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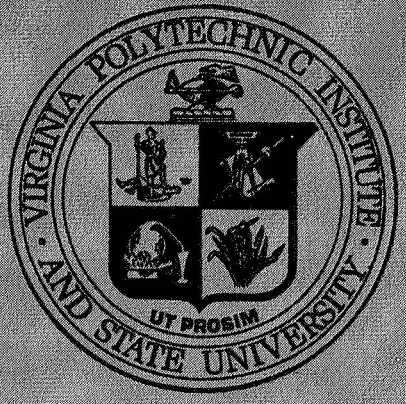
Final Report for Third Year of Work

on

A DEPOLARIZATION AND ATTENUATION EXPERIMENT USING THE COMSTAR AND CTS SATELLITES



Virginia Polytechnic Institute
and State University
Electrical Engineering
BLACKSBURG, VIRGINIA 24061

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on

A DEPOLARIZATION AND ATTENUATION EXPERIMENT USING THE COMSTAR AND CTS SATELLITES

Text by

C. W. Bostian
S. M. Babula
J. R. Dent
R. E. Dombroski
S. O. Lane
E. A. Manus
R. E. Marshall
D. N. Meadows
W. L. Stutzman
P. H. Wiley

Computer Artwork and Programming by
Peter Santago

Graphics by
Cynthia Will

Electrical Engineering Department
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061

Prepared for

NASA Goddard Space Flight Center
Greenbelt, Maryland 20771

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1. INTRODUCTION

This report summarizes attenuation and rain rate data collected during the 1978 calendar year on downlink paths from the CTS spacecraft (11.7 GHz) and the COMSTAR family of satellites (19.04 and 28.56 GHz). For information on the experimental hardware the reader should consult QUARTERLY TECHNICAL PROGRESS REPORT I ON A DEPOLARIZATION AND ATTENUATION EXPERIMENT USING THE COMSTAR AND CTS SATELLITES by C. W. Bostian, S. B. Holt, S. R. Kauffman, E. A. Manus, R. E. Marshall, W. P. Overstreet, R. R. Persinger, W. L. Stutzman, and P. H. Wiley, dated December 22, 1976. Details on the data reduction procedure used are contained in FINAL REPORT (SECOND YEAR OF WORK) ON A DEPOLARIZATION AND ATTENUATION EXPERIMENT USING THE COMSTAR AND CTS SATELLITES by C. W. Bostian, S. R. Kauffman, E. A. Manus, R. E. Marshall, W. P. Overstreet, R. R. Persinger, W. L. Stutzman, and P. H. Wiley, dated February 9, 1978. Both reports were submitted for Contract NAS5-22577.

All 11.7 GHz data presented were taken with the CTS spacecraft at a nominal elevation angle of 33 degrees. The 19.04 GHz data for January through August were taken from COMSTAR D-2 at 44 degrees elevation; D-2 was turned off at the end of August and subsequent data were collected with D-3 at 46 degrees elevation. Because of problems with the D-2 spacecraft, the 28.56 data came from three satellites: D-2 (44 degrees elevation) for January through mid June, D-1 (24.5 degrees elevation) for part of July and August, and D-3 (46 degrees elevation) after September 1.

2. ATTENUATION AND RAINRATE STATISTICS

2.1 Introduction

The data which follow are for rain only. Because of inherent problems in handling snow events (antennas fill with snow, rain gauges freeze, etc.), snow data have been excluded from the data base reported here. While snow fell in January, February, March, April, and November, the time excluded was a significant fraction of a month only in January.

Table 2.1-1 summarizes the data collected for each month of 1978. The top row lists the hours of rain; the other rows give the number of rain hours for which signal data were processed for this report. Most of the differences in rain time and signal time are small and result from ground equipment down time or spacecraft interruptions. March is an exception because about seven hours of the observed rain was mixed with snow.

Table 2.1-1. Summary of 1978 Operations. The numbers indicate the hours of rain data and hours of useful signal data during rain for each month. Both are calculated to the nearest integer hour.

	J	F	M	A	M	J	J	A	S	O	N	D	Total
Hours of Rain	16	0	24	4	6	9	6	5	1	3	11	28	113
11.7 Co	16	0	17	4	6	9	6	4	1	1	11	20	95
11.7 X	16	0	17	3	5	9	6	5	1	1	11	19	93
19.04V Co	16	0	7	0	2	6	6	5	0	3	11	28	84
19.04V X	16	0	6	0	1	4	6	4	0	3	11	28	79
19.04H Co	16	0	6	0	2	6	6	5	0	3	11	28	83
19.04H X	15	0	6	0	1	4	6	4	0	3	10	25	74
28.56 Co	16	0	17	4	5	5	0	5	1	3	10	28	94
28.56 X	16	0	17	3	5	5	0	5	1	3	10	27	92

2.2 Monthly Exceedence Plots

The figures which follow present percent-of-time data for attenuation and rain rate during each month of the calendar year. Several comments on these are in order.

1. No rain fell in February. Therefore no rain rate plot is presented and the signal statistics represent fades caused by orbital motion, ice, or snow somewhere in the propagation paths.
2. The 19.04 GHz data shown for April and September are estimated from data collected on the 28 GHz downlink.
3. The 28.56 GHz data for July and August are for the D-1 spacecraft at a low (24.5 degrees) elevation angle. Some of these in July are estimated from 19.04 GHz data.
4. The January percent-of-time plots represent only the two short time periods during the month when rain - rather than snow - fell. These extended from about 0000 (UT) on January 8 until 0600 on January 9 and from 1800 on January 25 until 1000 on January 26. The two periods were combined to form the data base for January. All of the other monthly data reported are for full calendar months except for July where the timebase begins on July 2.

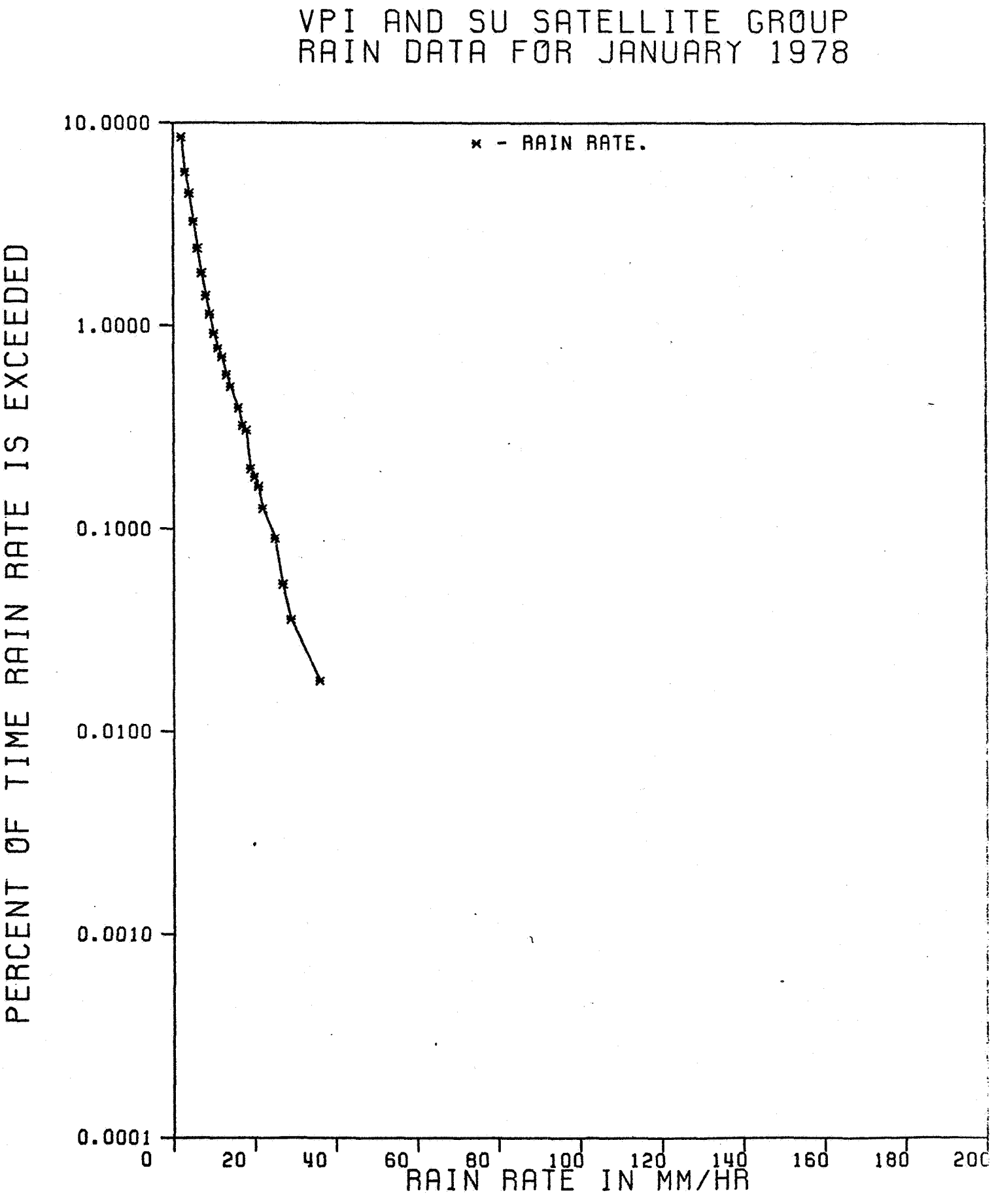

Figure 2.2-1. Rain rate percent of time data for January, 1978.

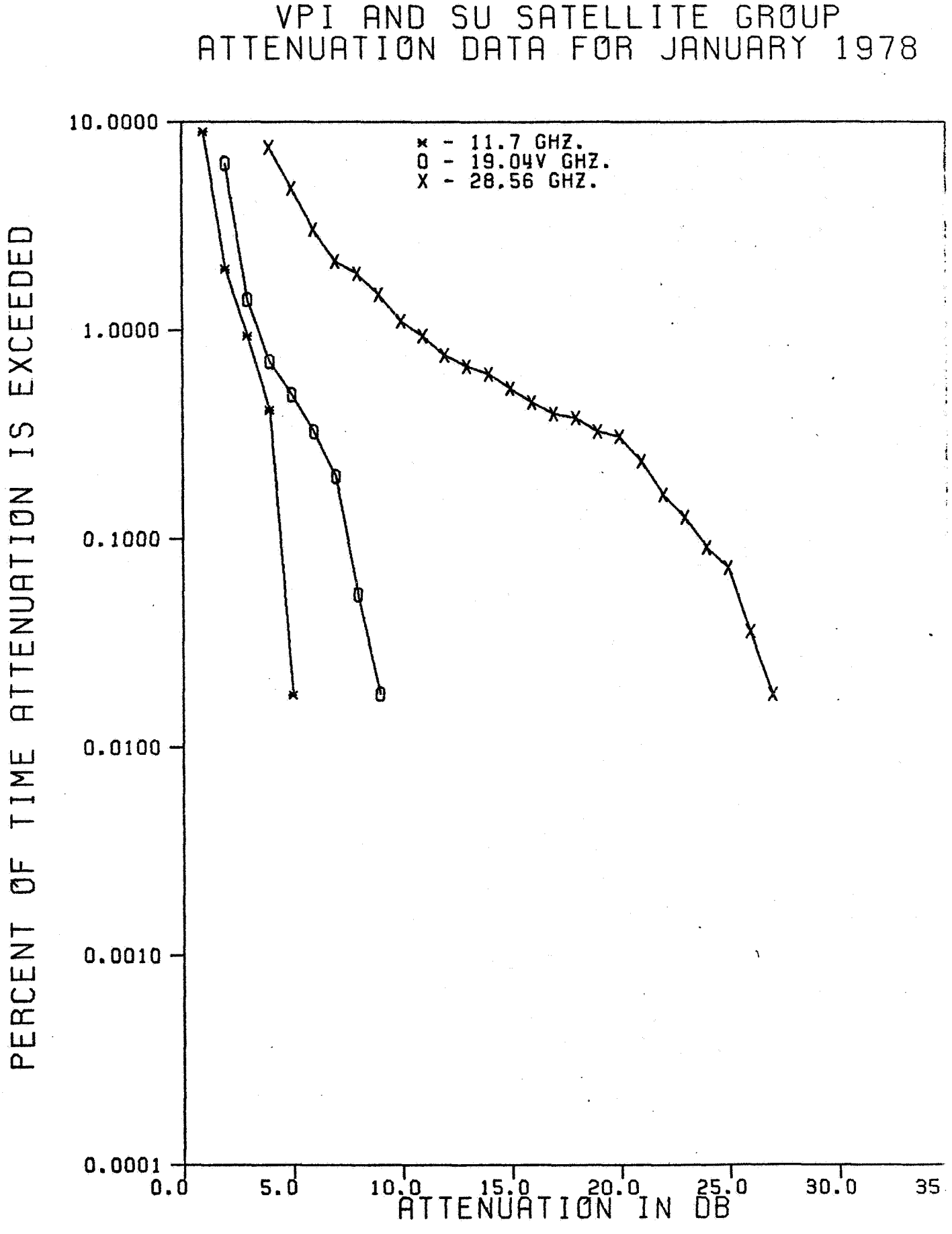

Figure 2.2-2. Attenuation percent of time data for January, 1978.

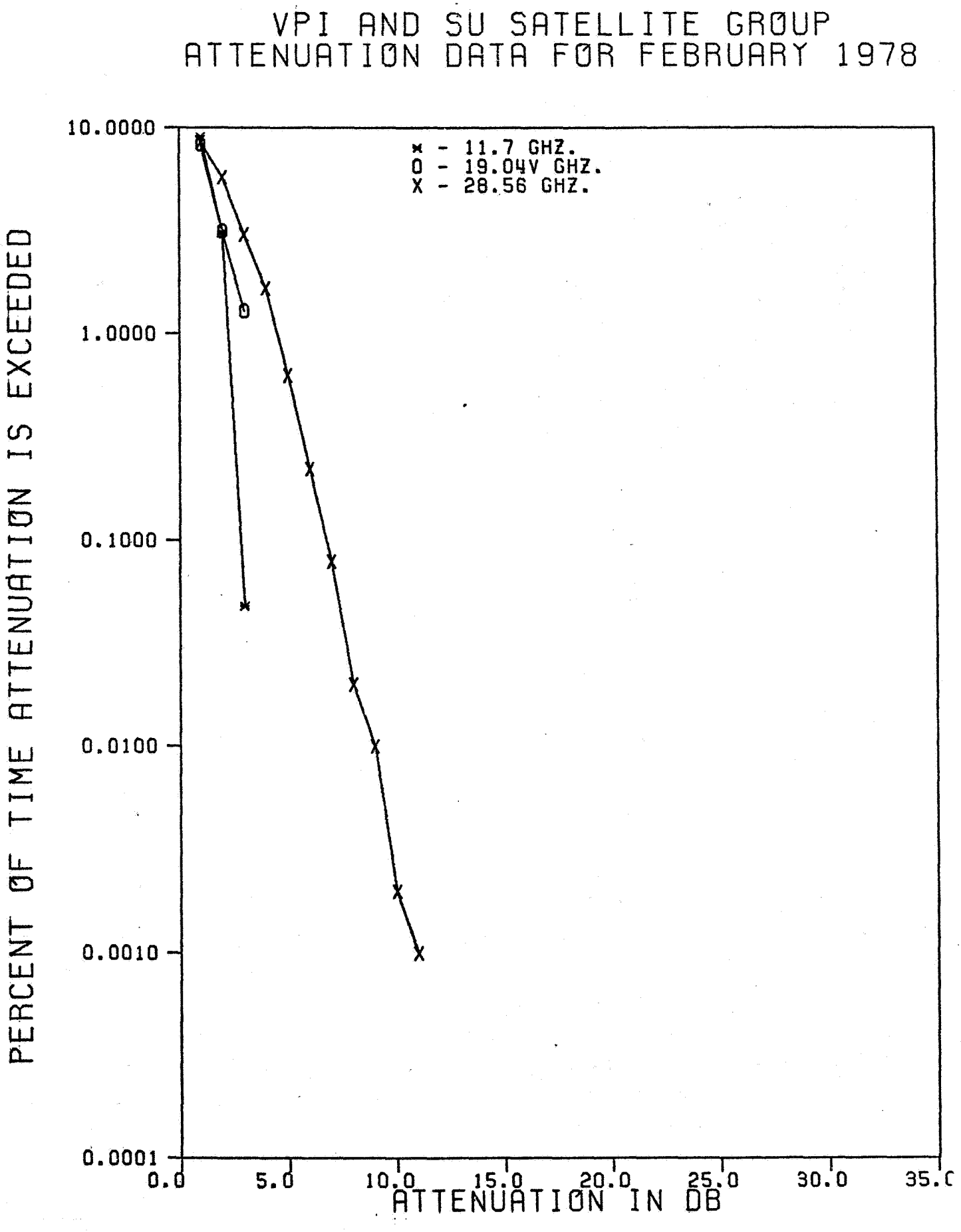

Figure 2.2-3. Attenuation percent of time data for February, 1978.

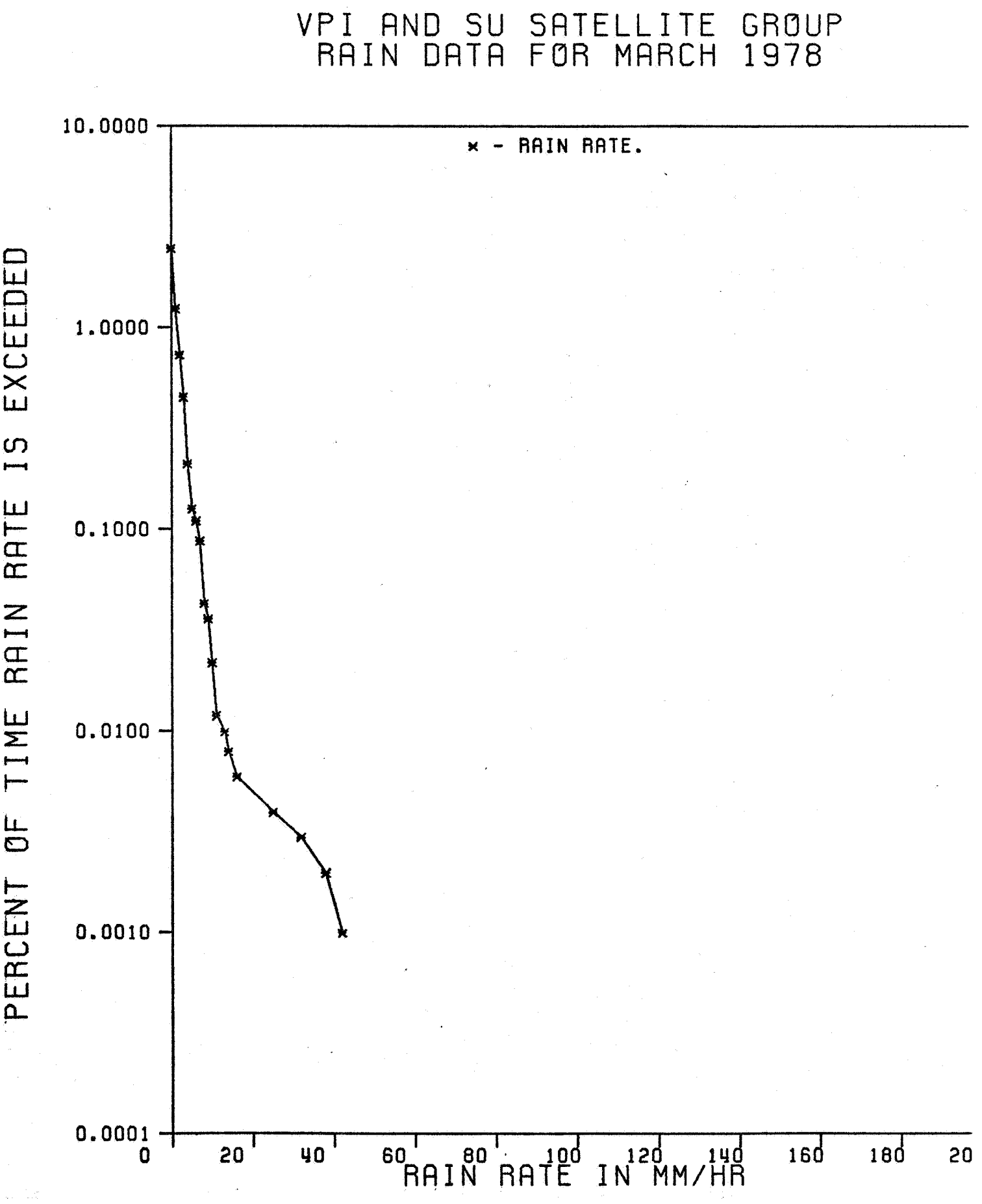

Figure 2.2-4. Rain rate percent of time data for March, 1978.

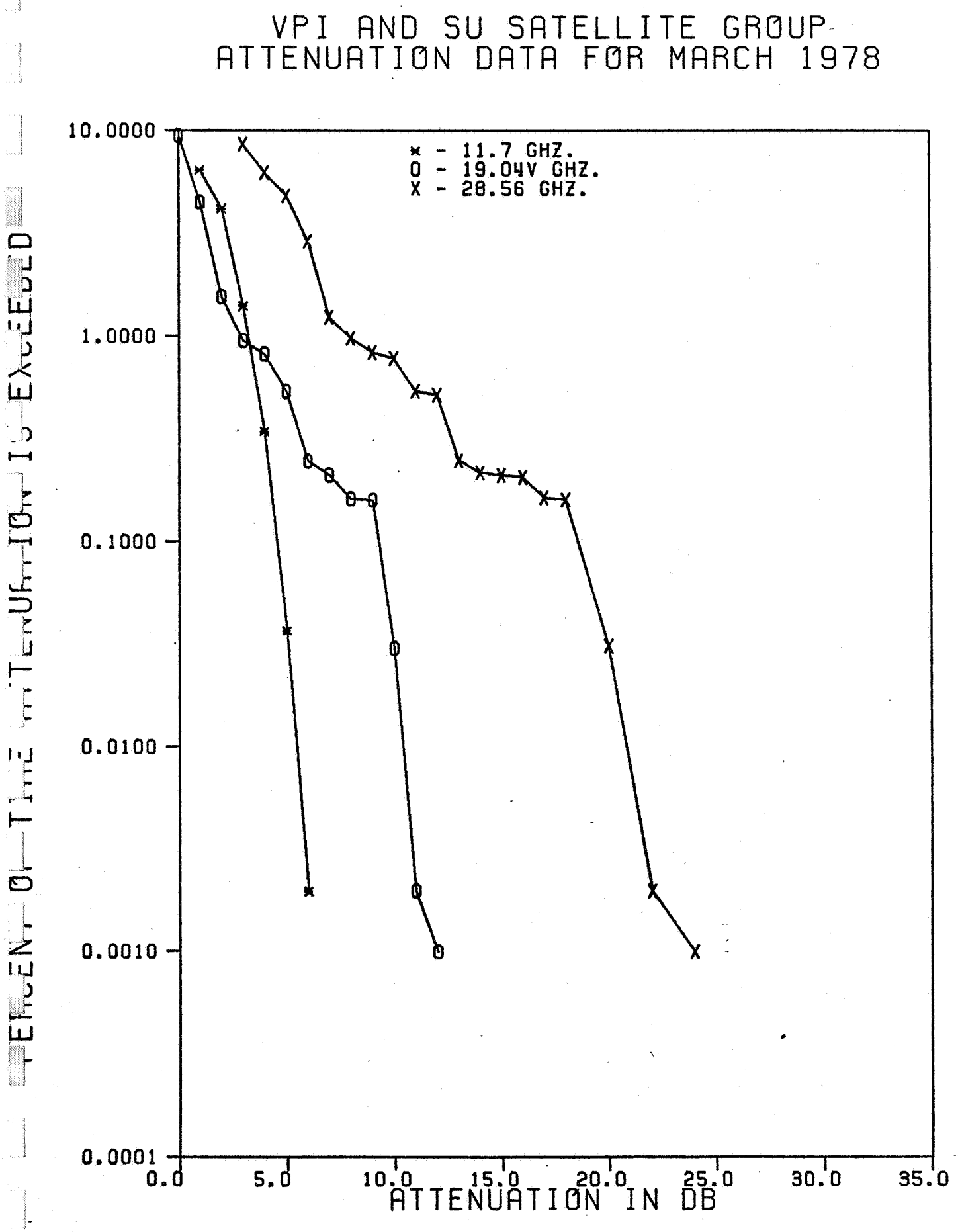

Figure 2.2-5. Attenuation percent of time data for March, 1978.

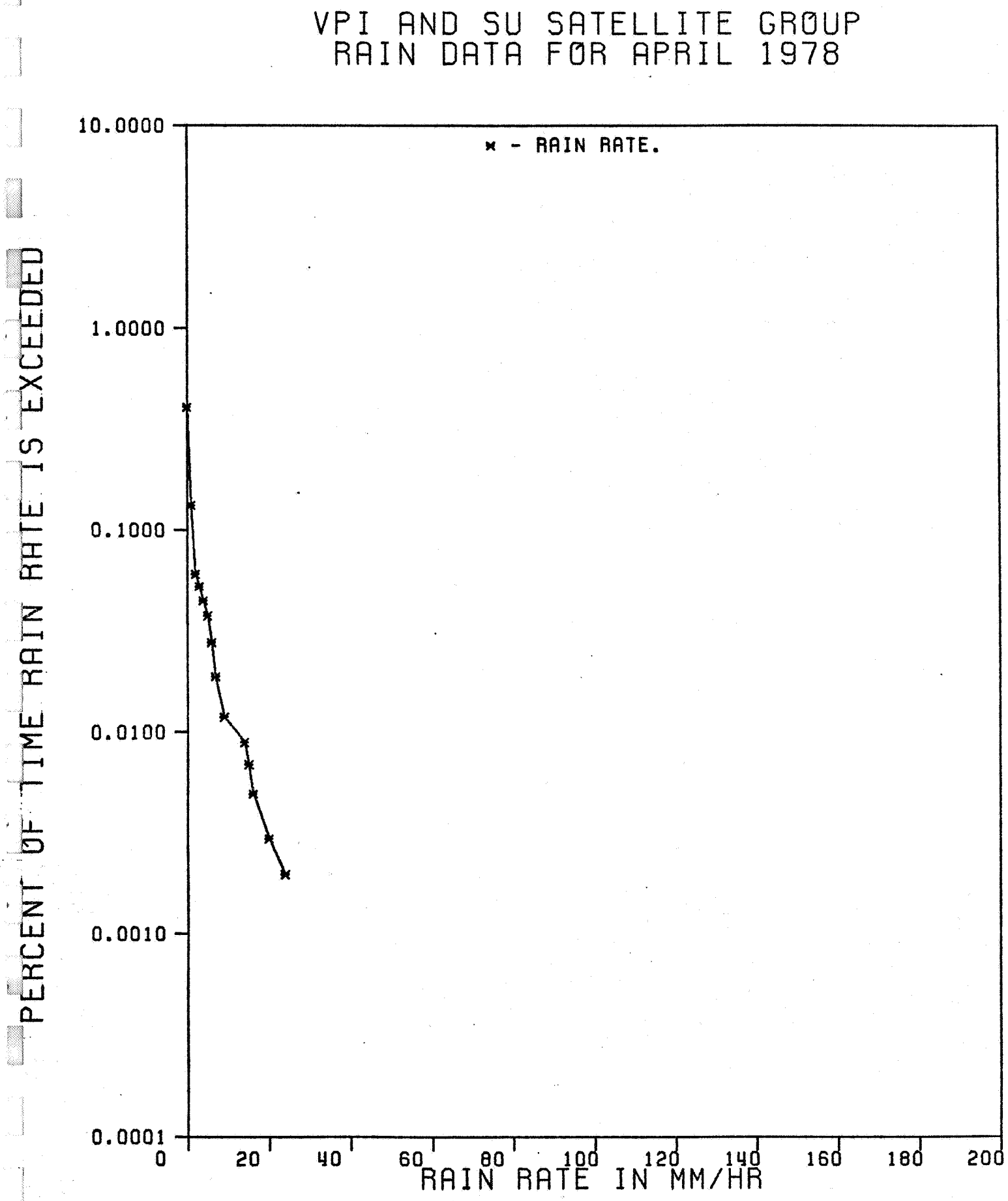

Figure 2.2-6. Rain rate percent of time data for April, 1978.

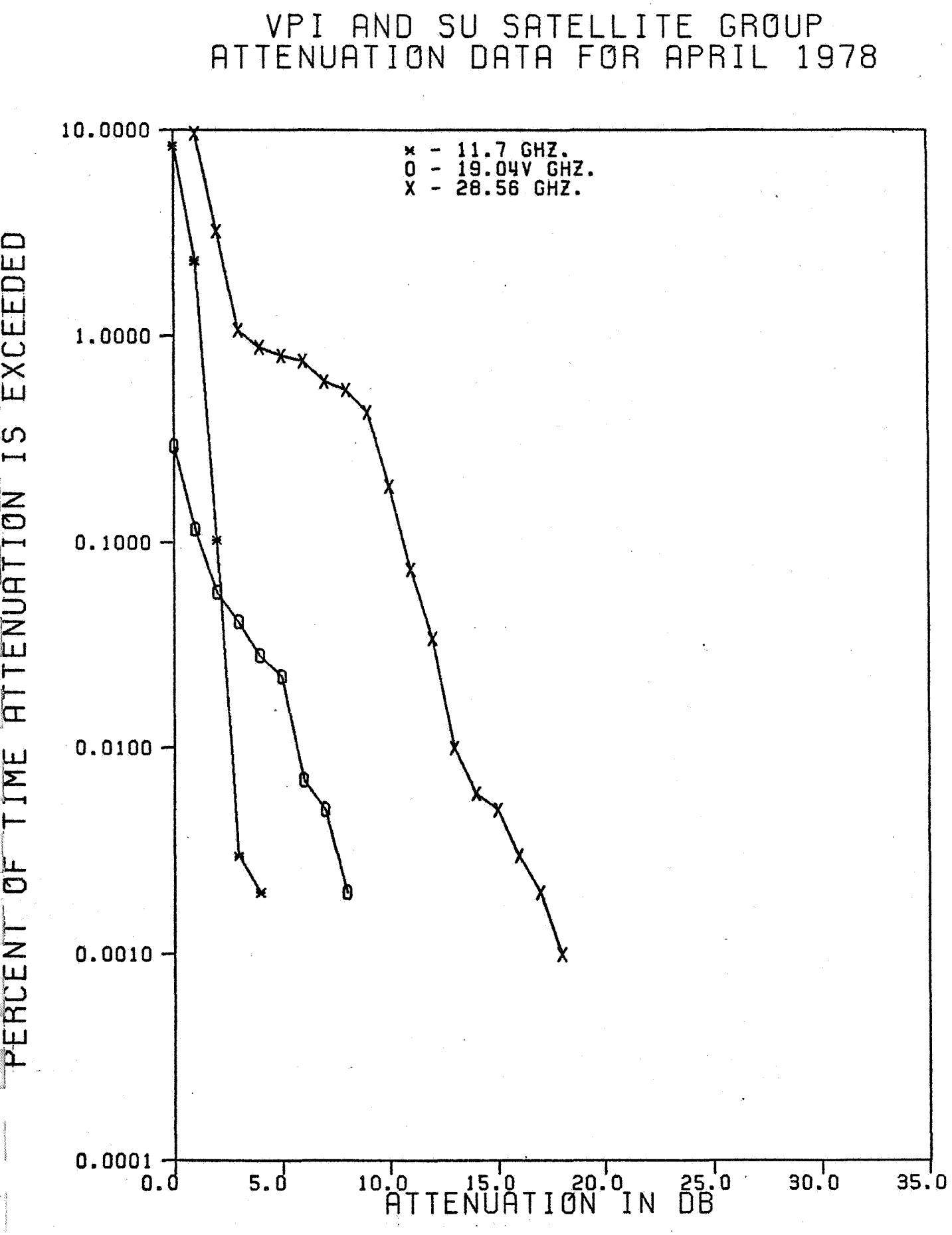

Figure 2.2-7. Attenuation percent of time data for April, 1978.

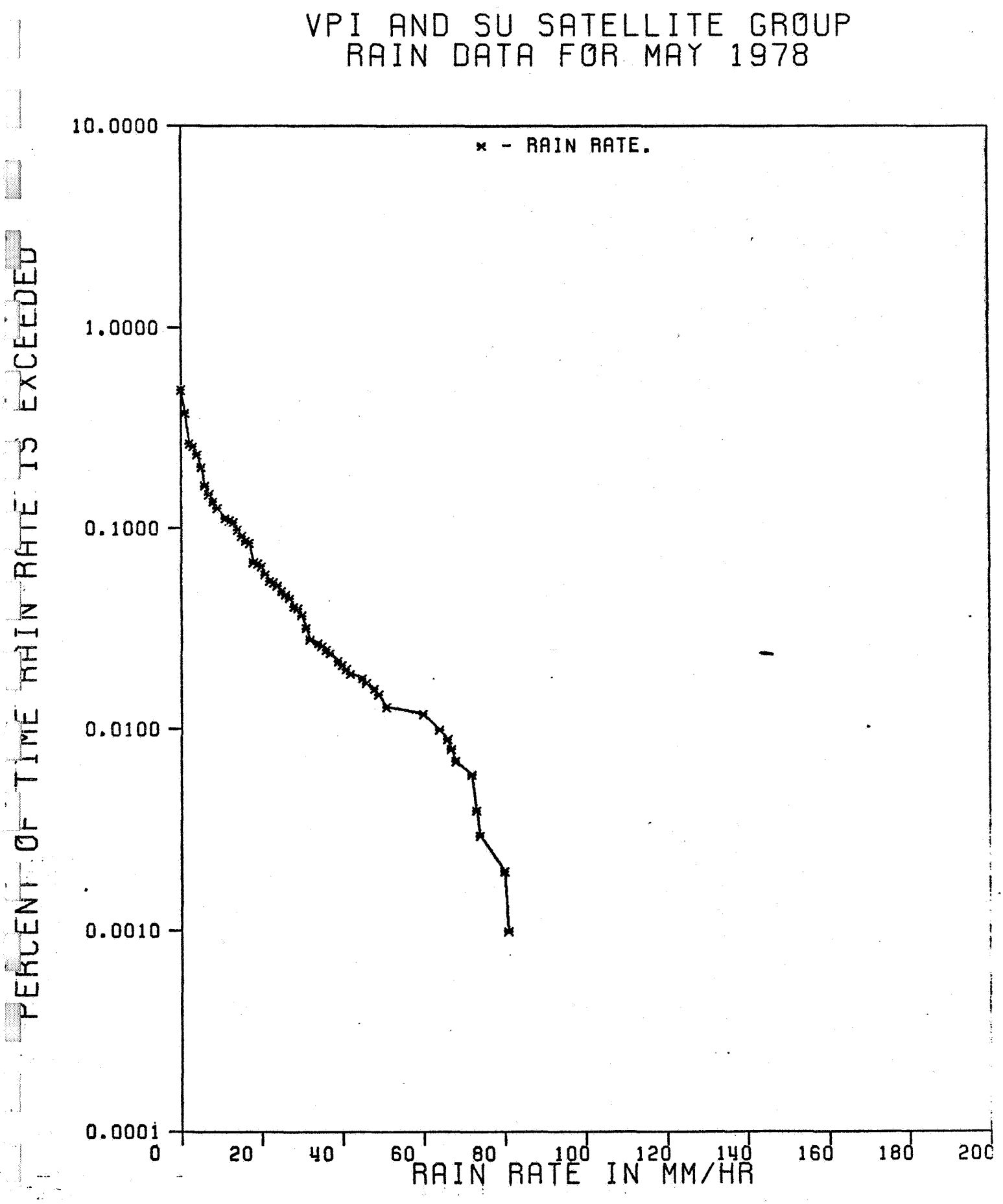

Figure 2.2-8. Rain rate percent of time data for May, 1978.

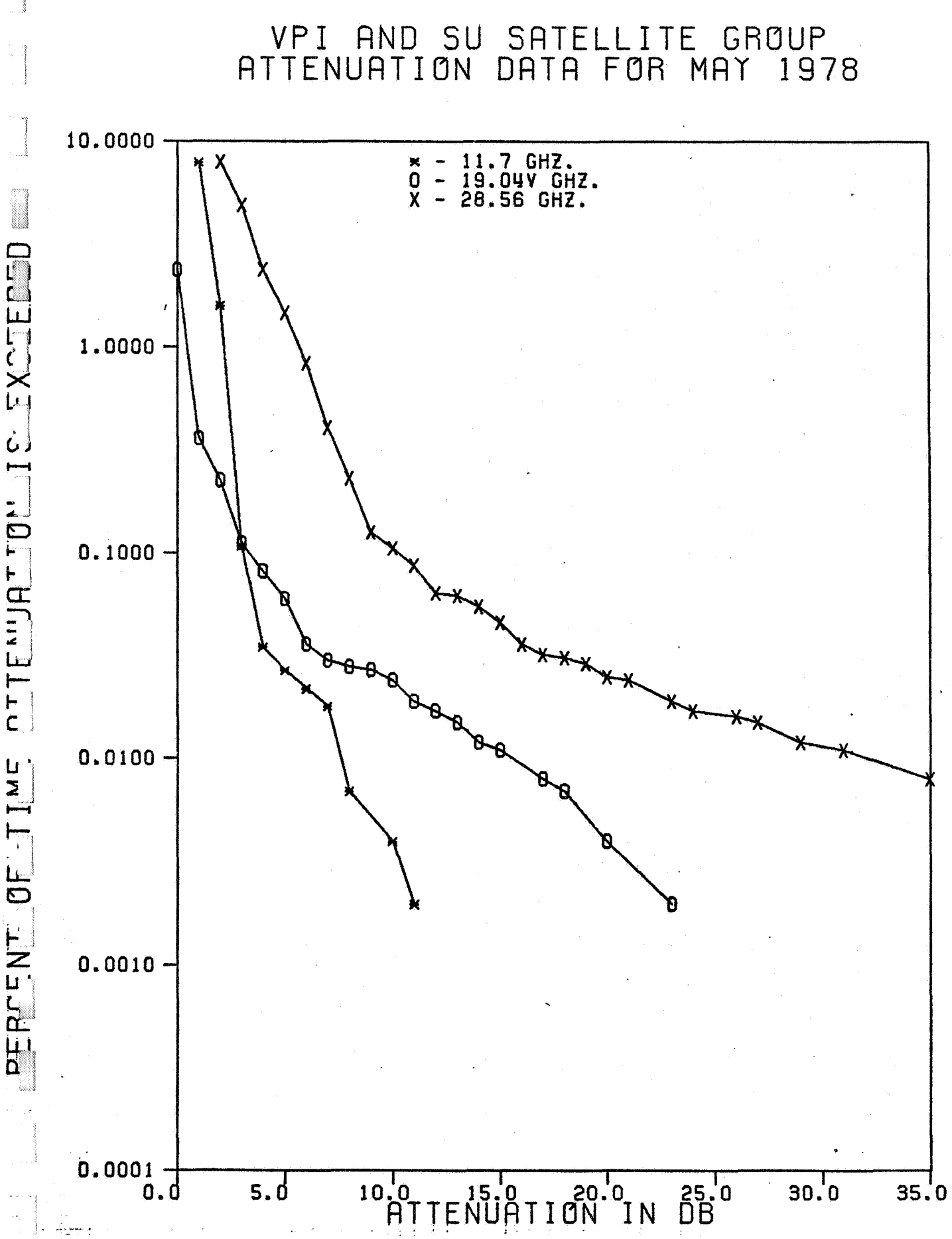

Figure 2.2-9. Attenuation percent of time data for May, 1978.

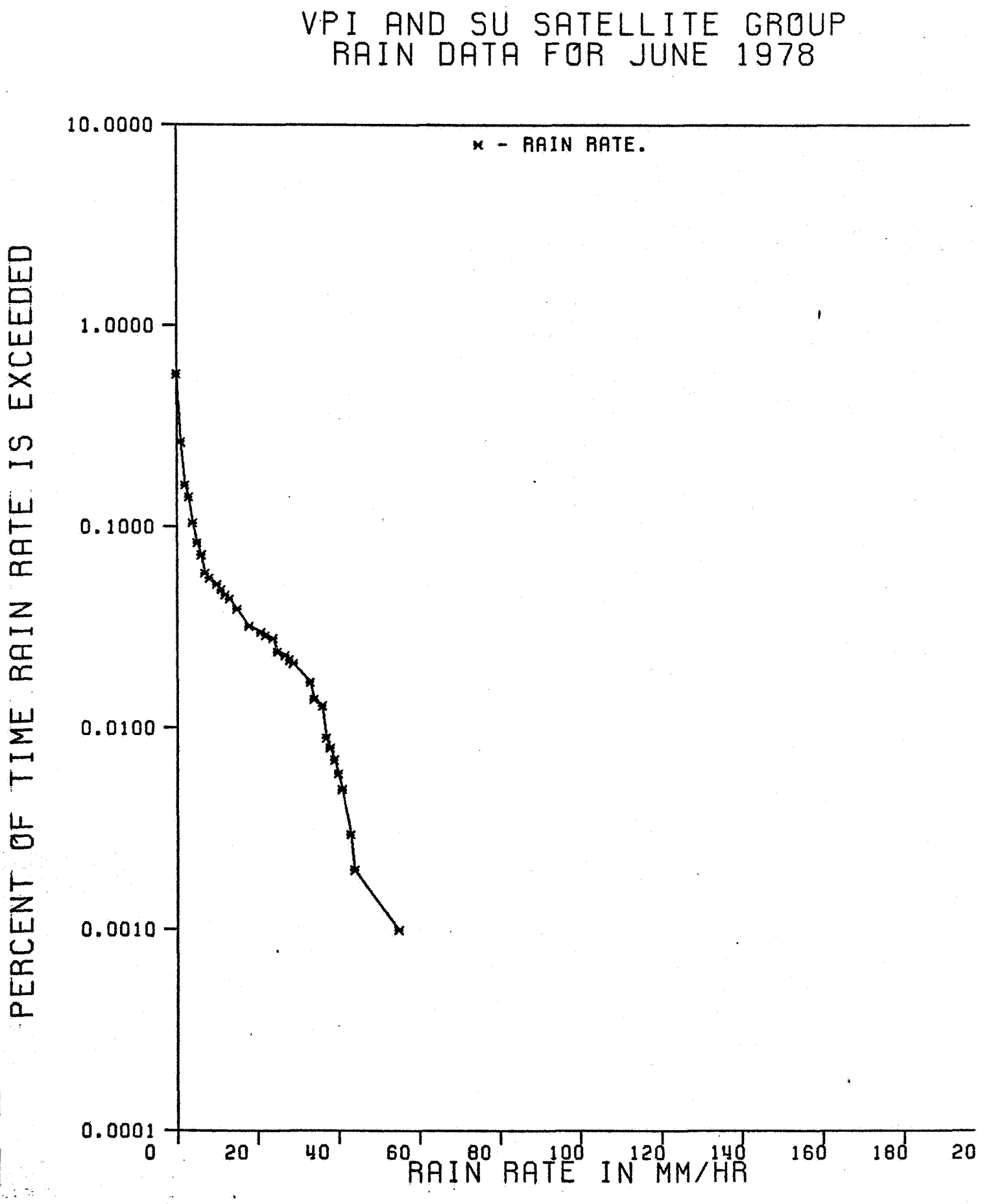

Figure 2.2-10. Rain rate percent of time data for June, 1978.

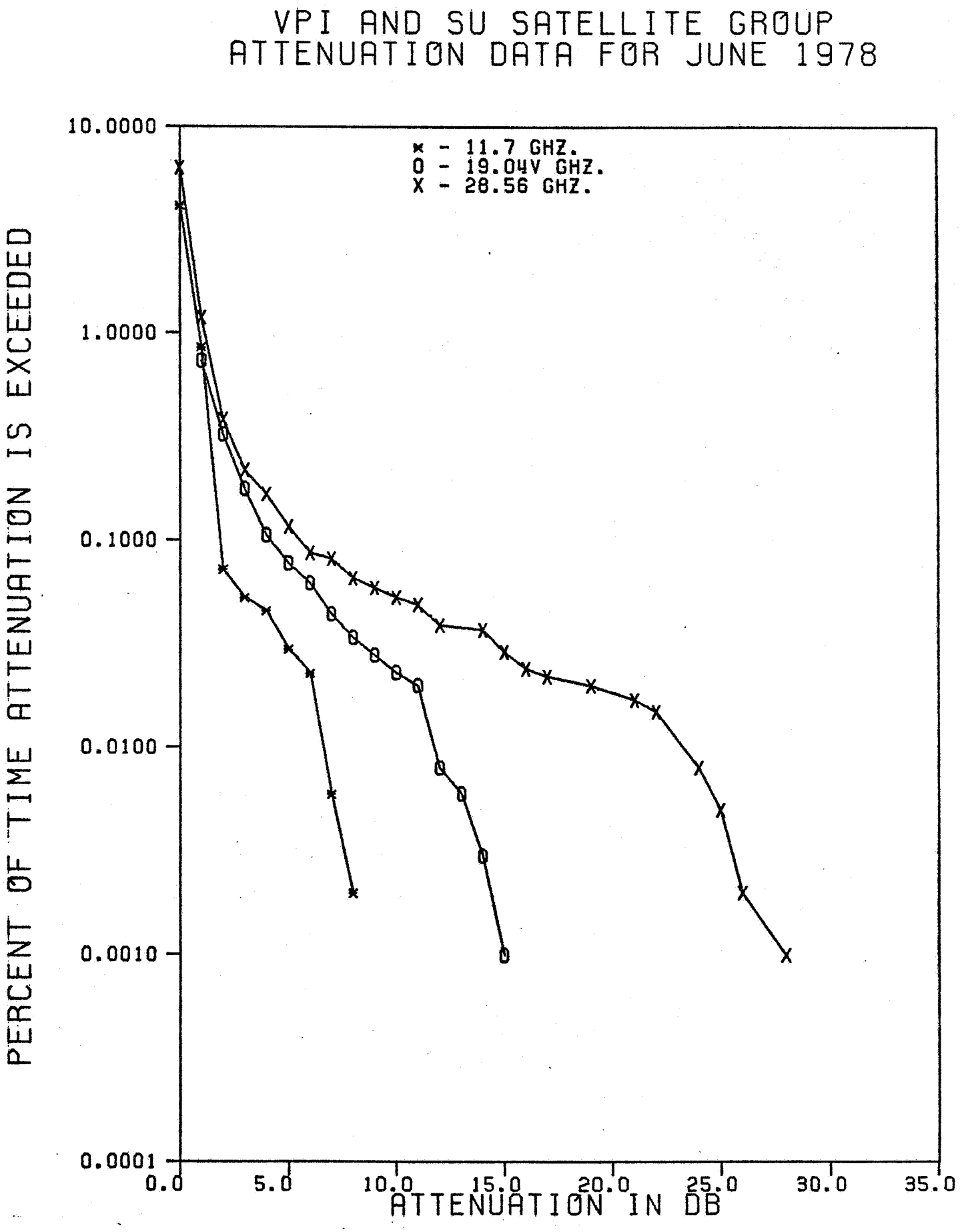

Figure 2.2-11. Attenuation percent of time data for June, 1978.

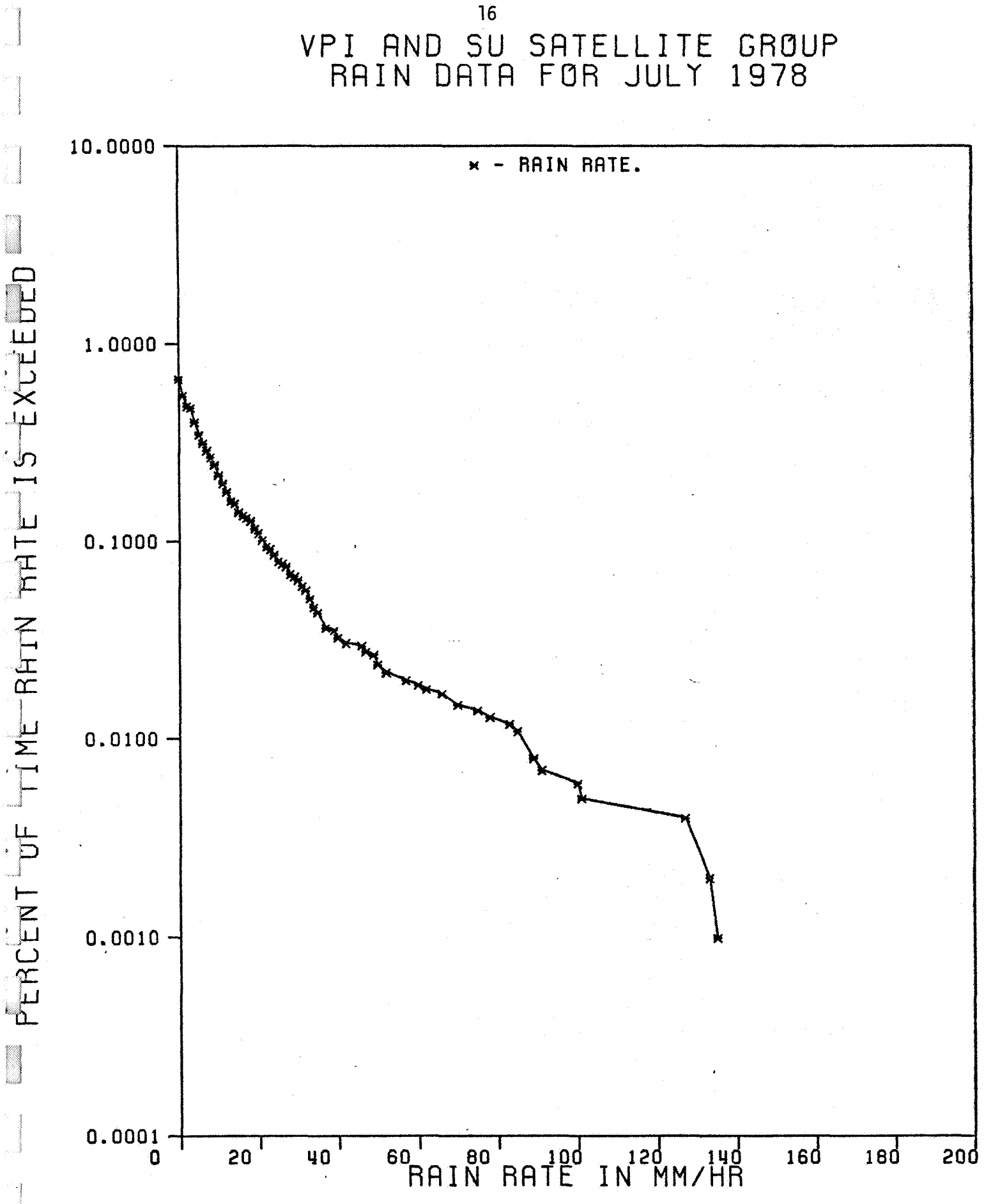

Figure 2.2-12. Rain rate percent of time data for July, 1978.

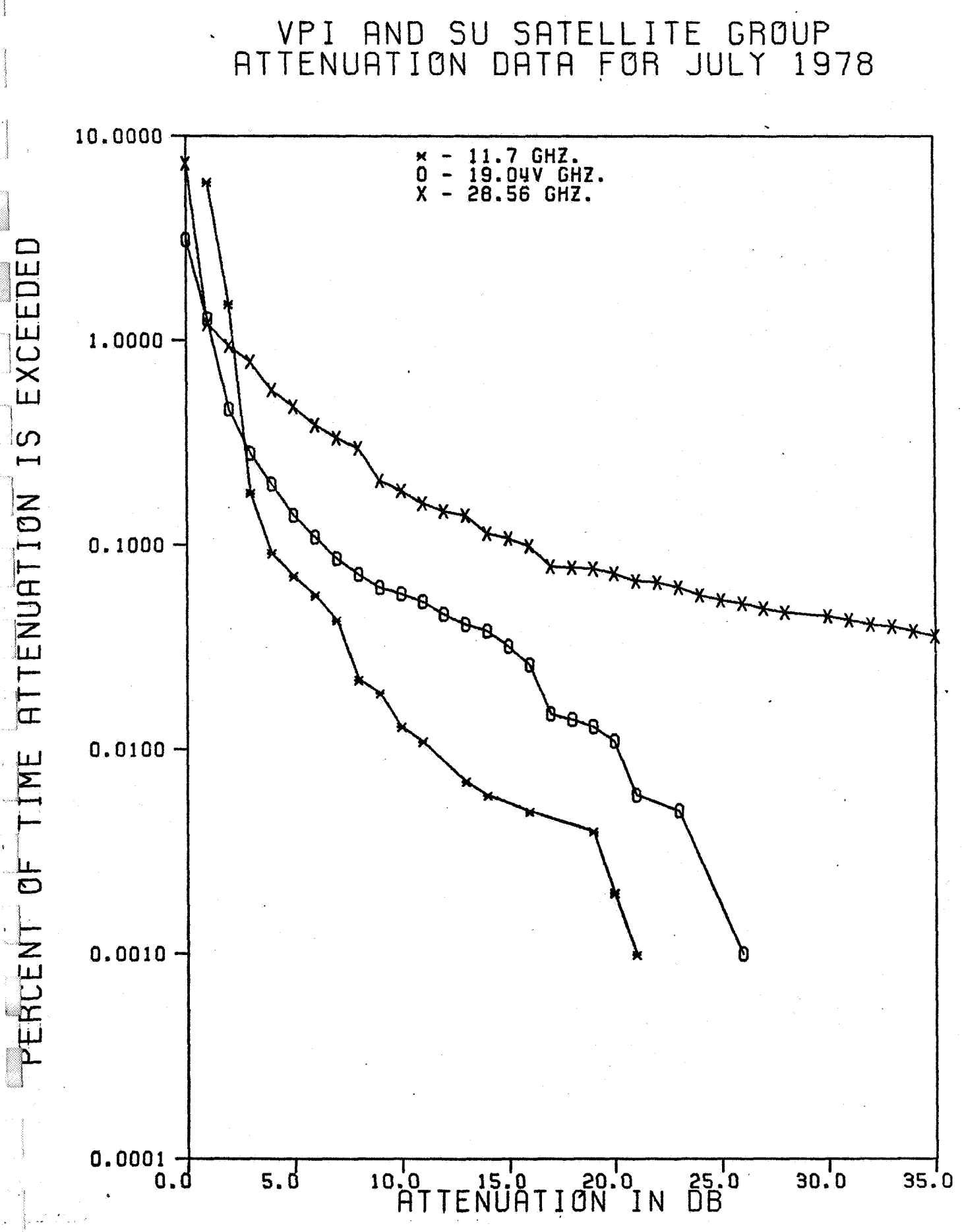

Figure 2.2-13. Attenuation percent of time data for July, 1978.

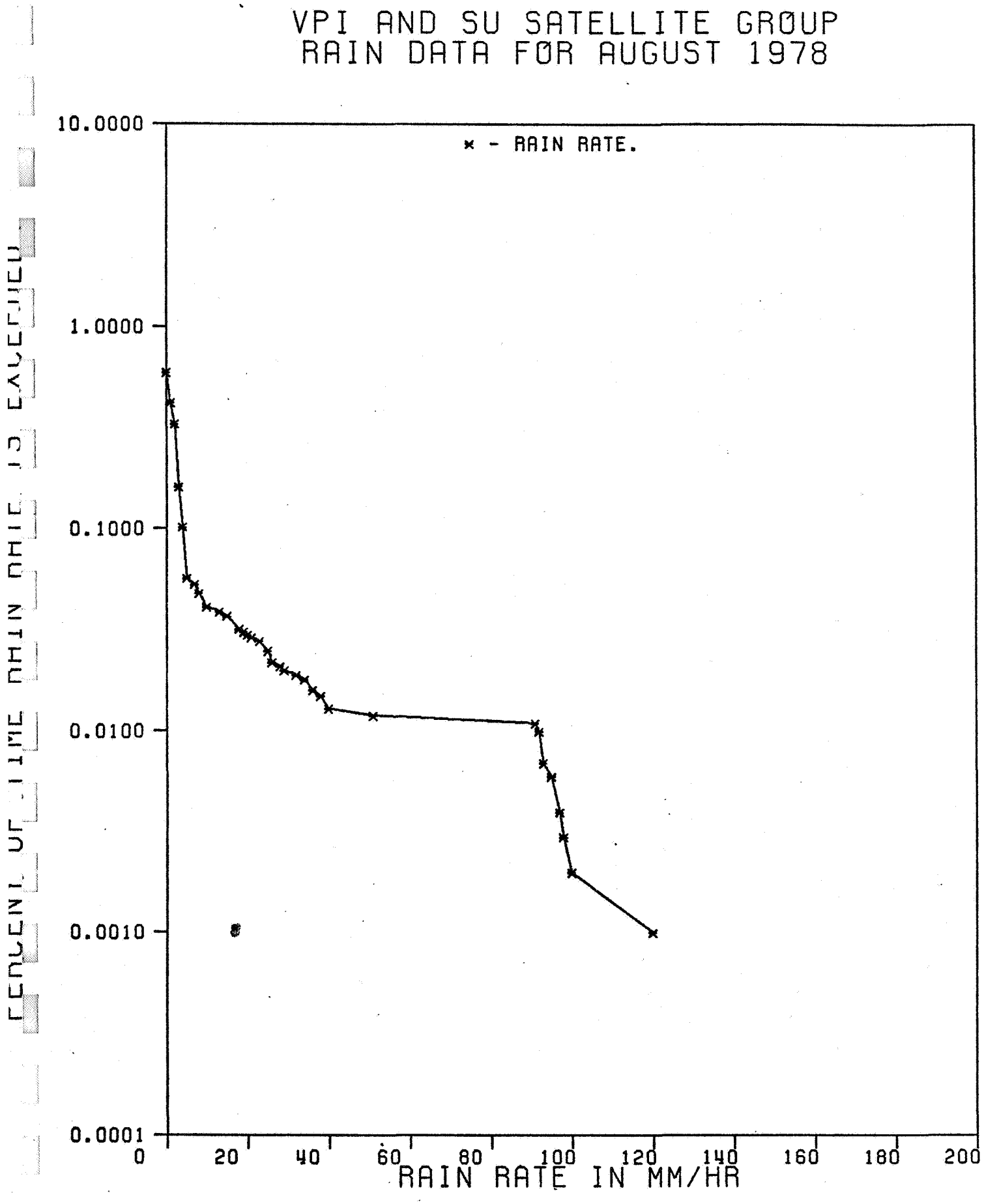

Figure 2.2-14. Rain rate percent of time data for August, 1978.

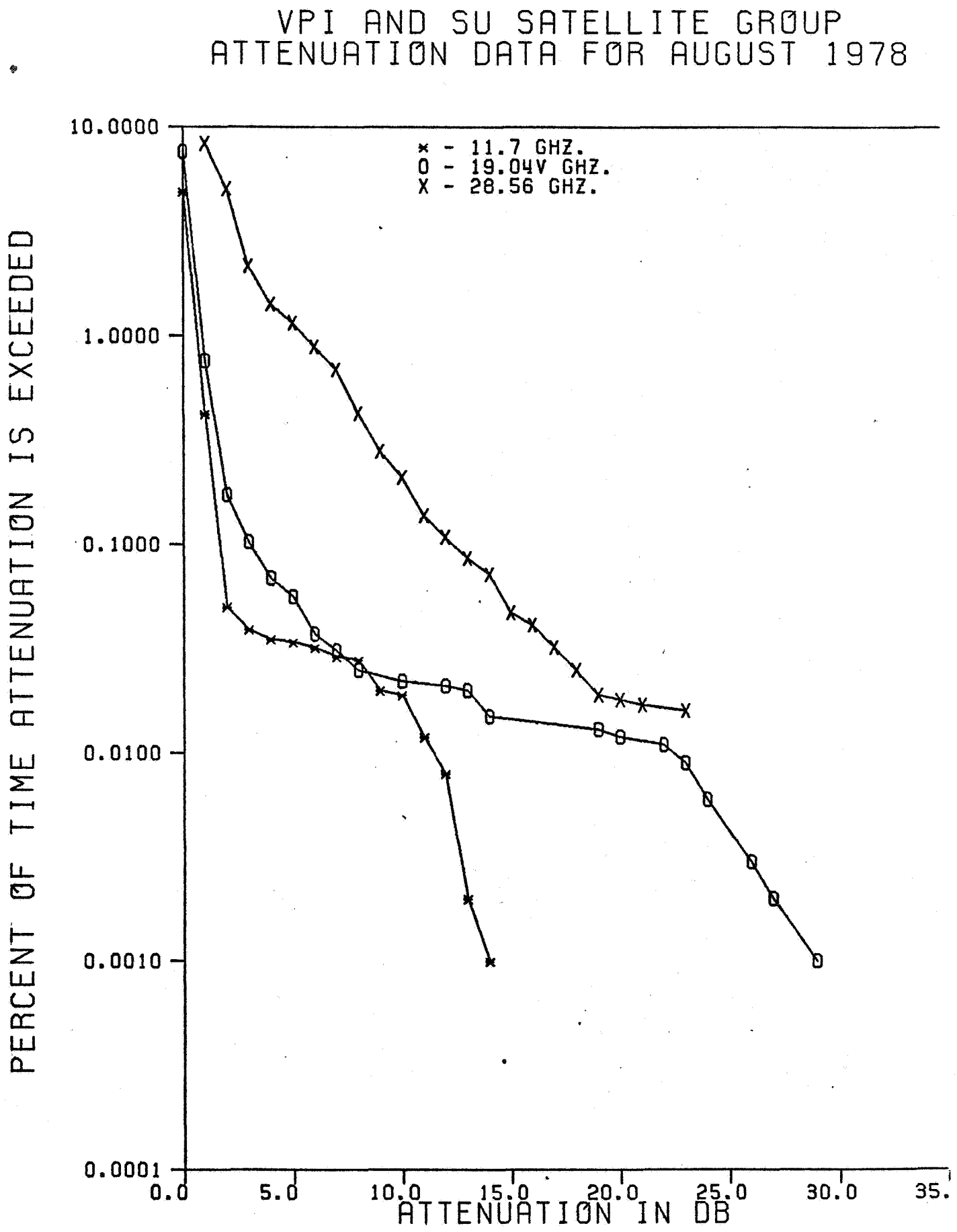

Figure 2.2-15. Attenuation percent of time data for August, 1978.

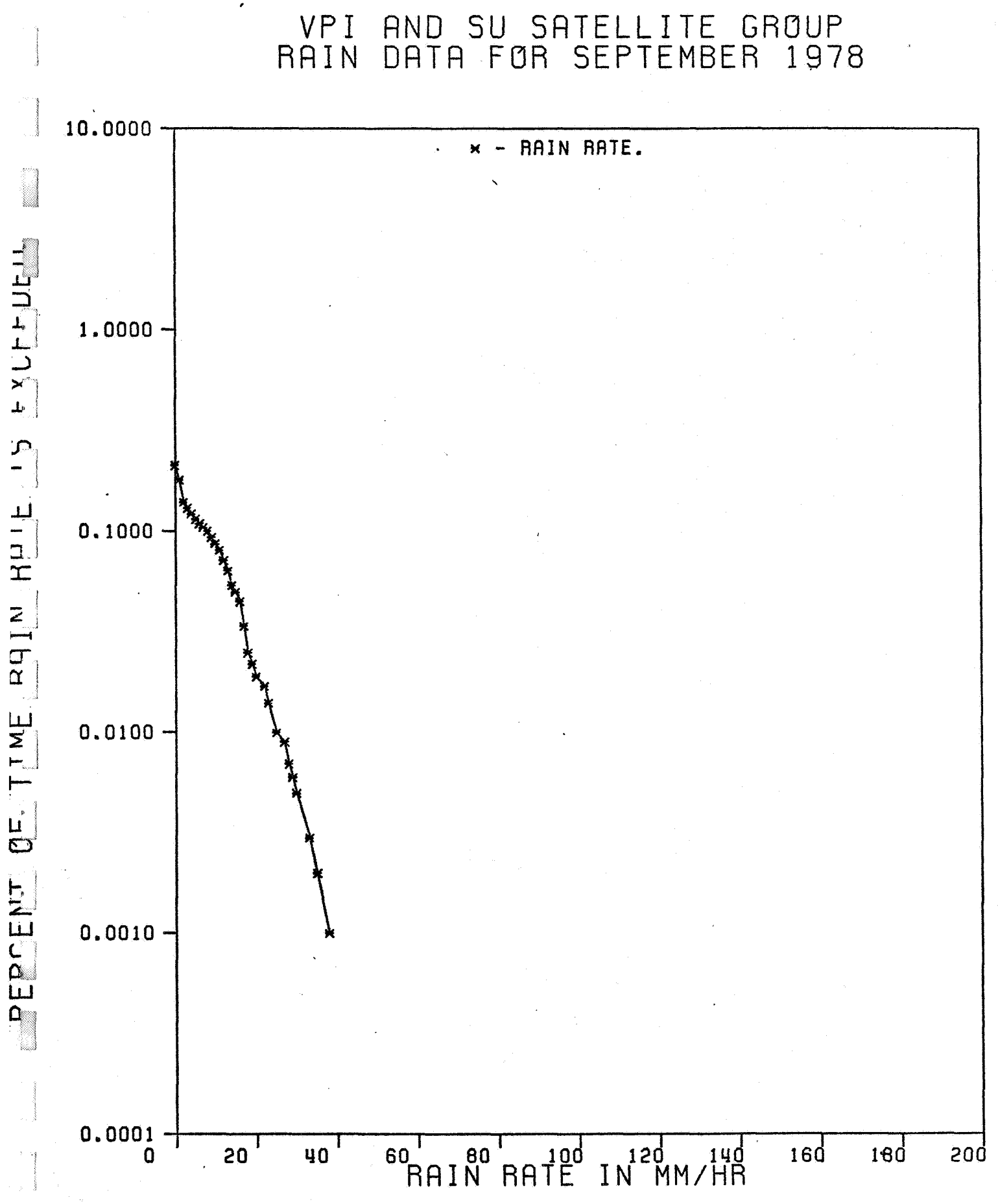

Figure 2.2-16. Rain rate percent of time data for September, 1978.

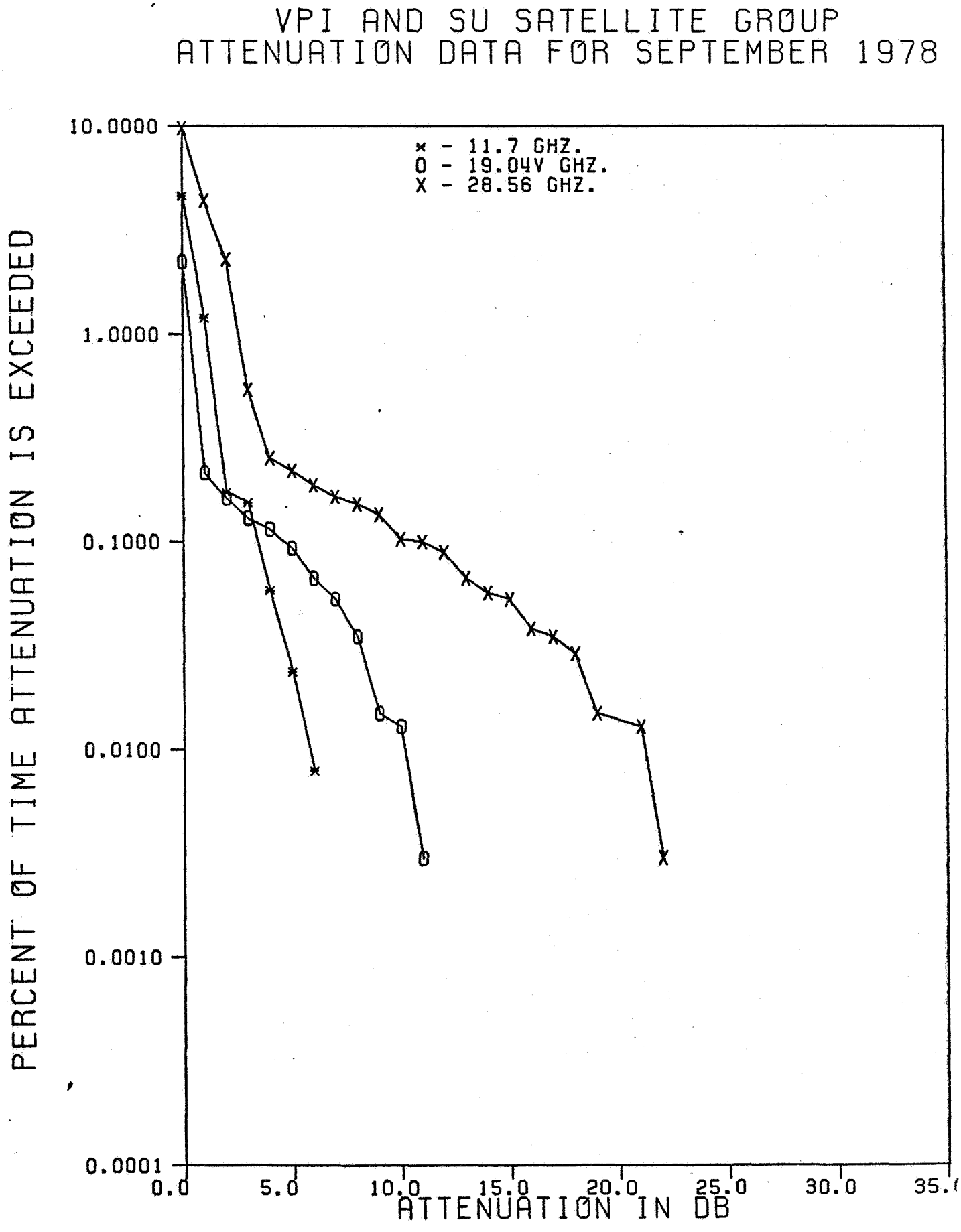

Figure 2.2-17. Attenuation percent of time data for September, 1978.

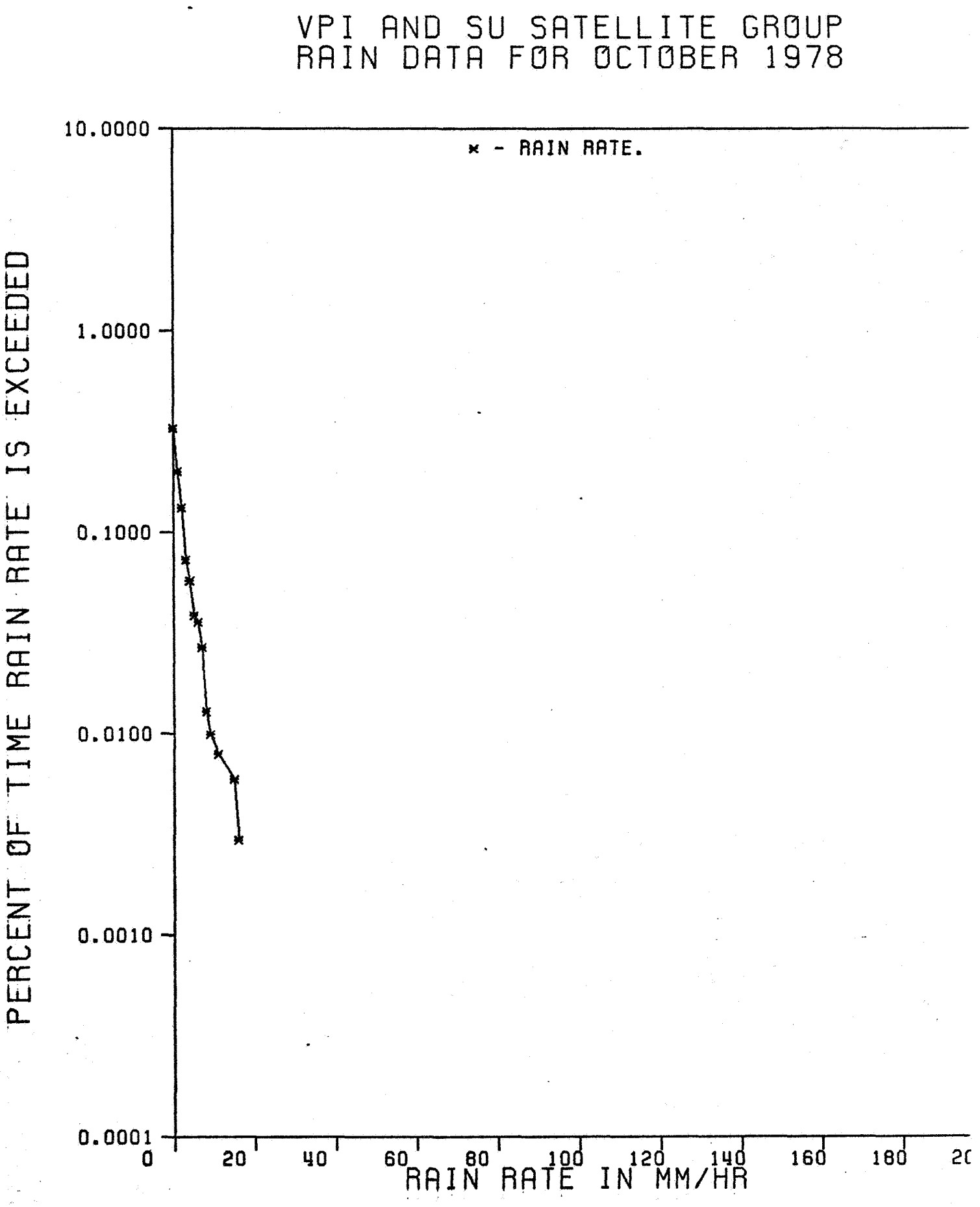

Figure 2.2-18. Rain rate percent of time data for October, 1978.

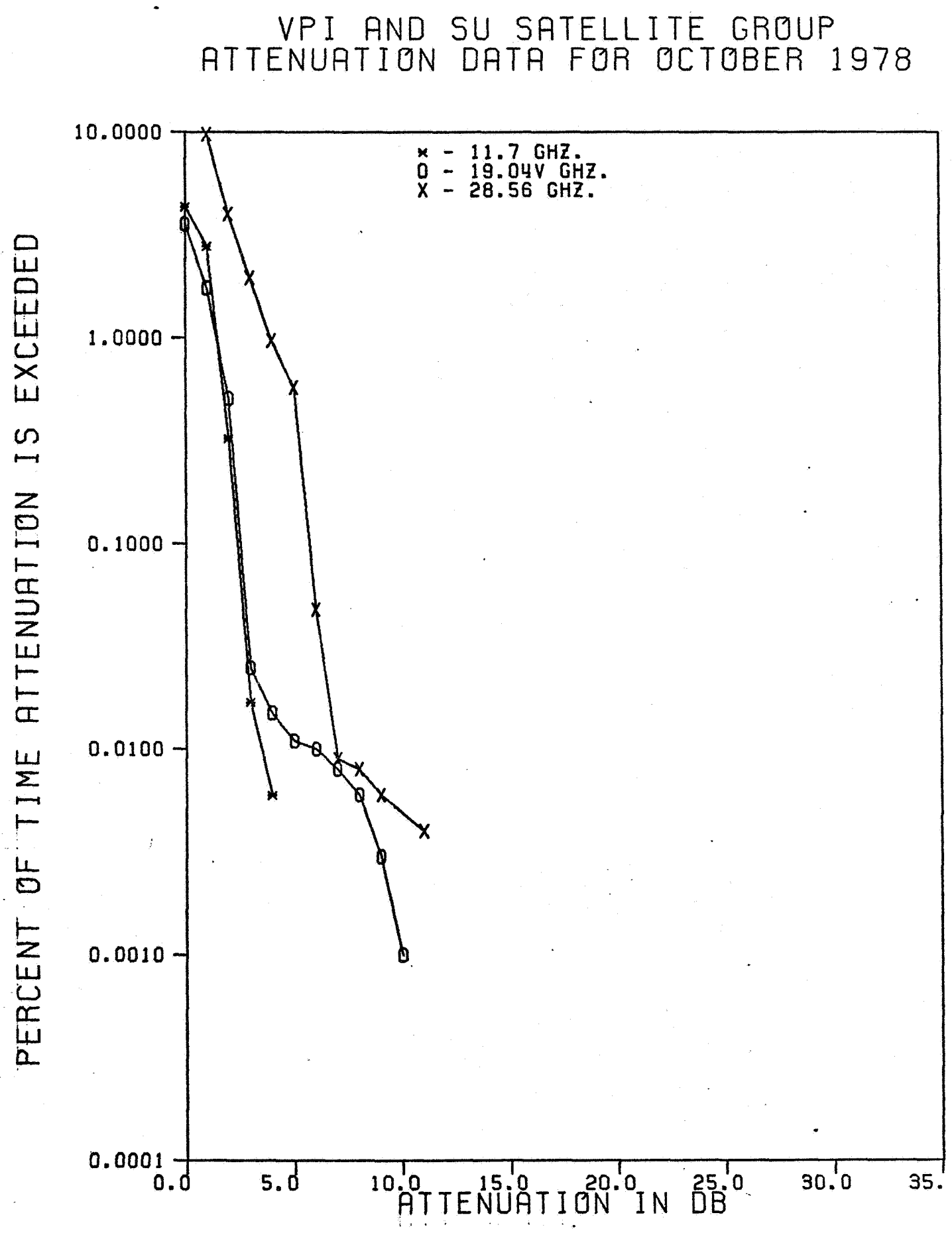

Figure 2.2-19. Attenuation percent of time data for October, 1978.

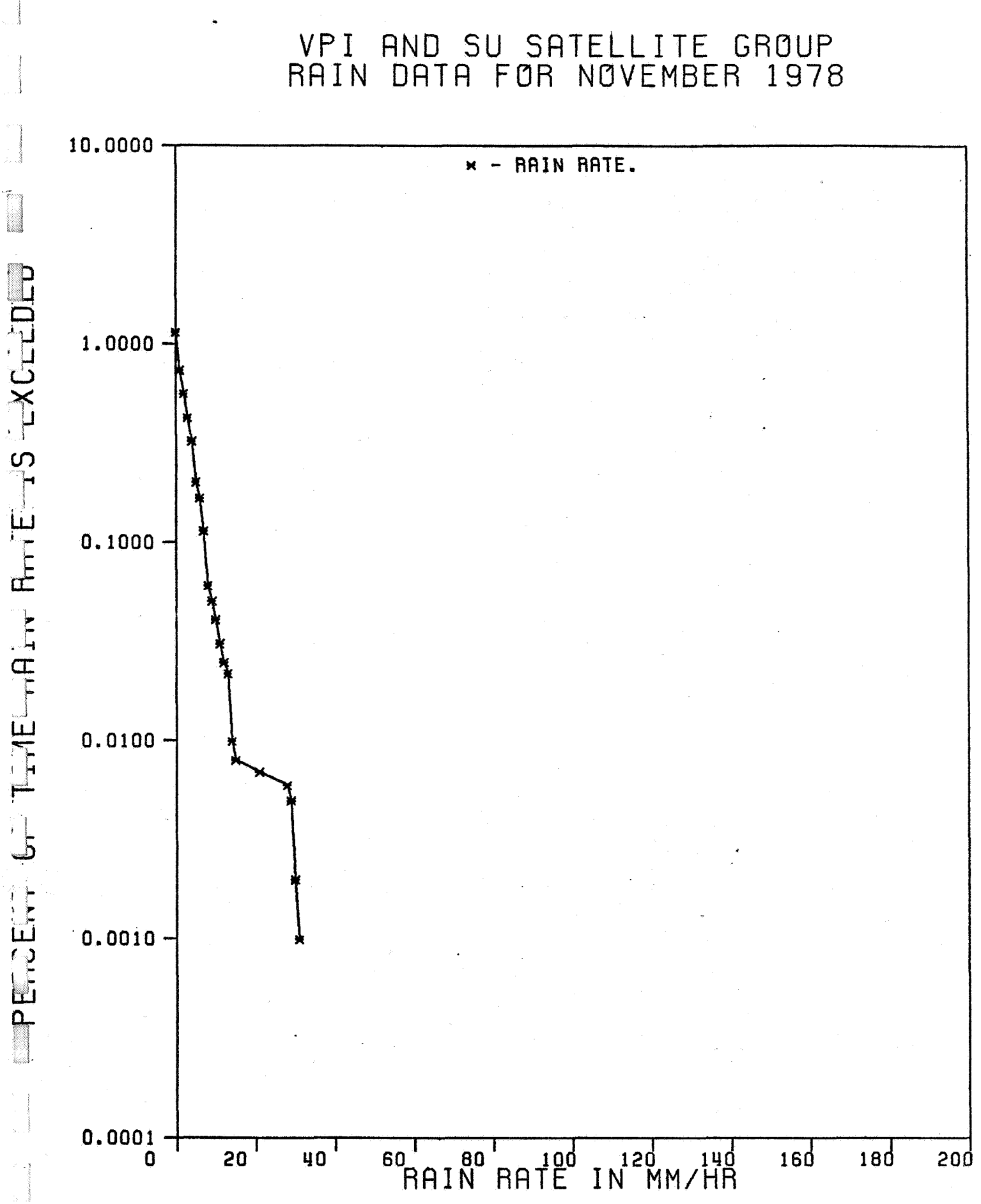

Figure 2.2-20. Rain rate percent of time data for November, 1978.

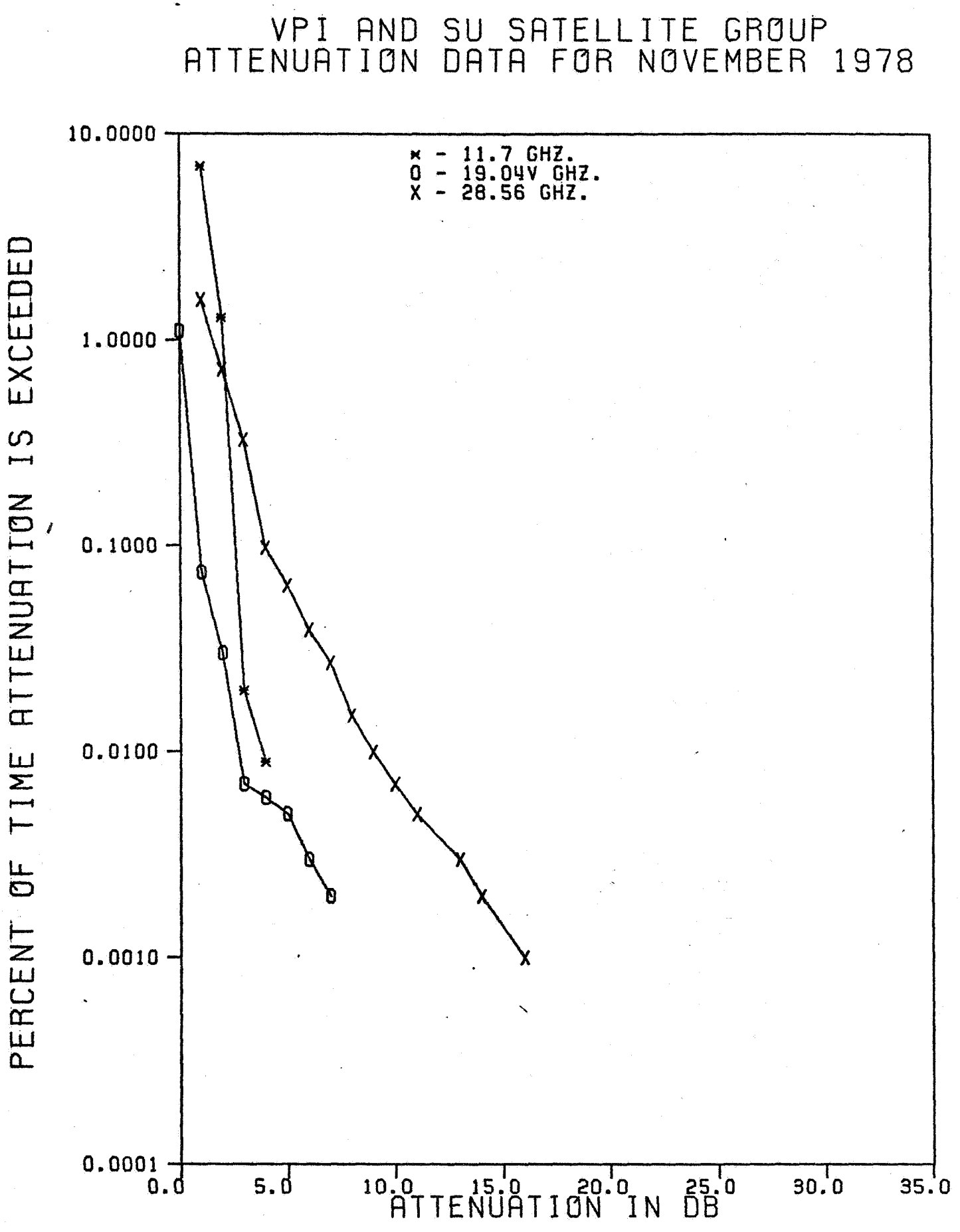

Figure 2.2-21. Attenuation percent of time data for November, 1978.

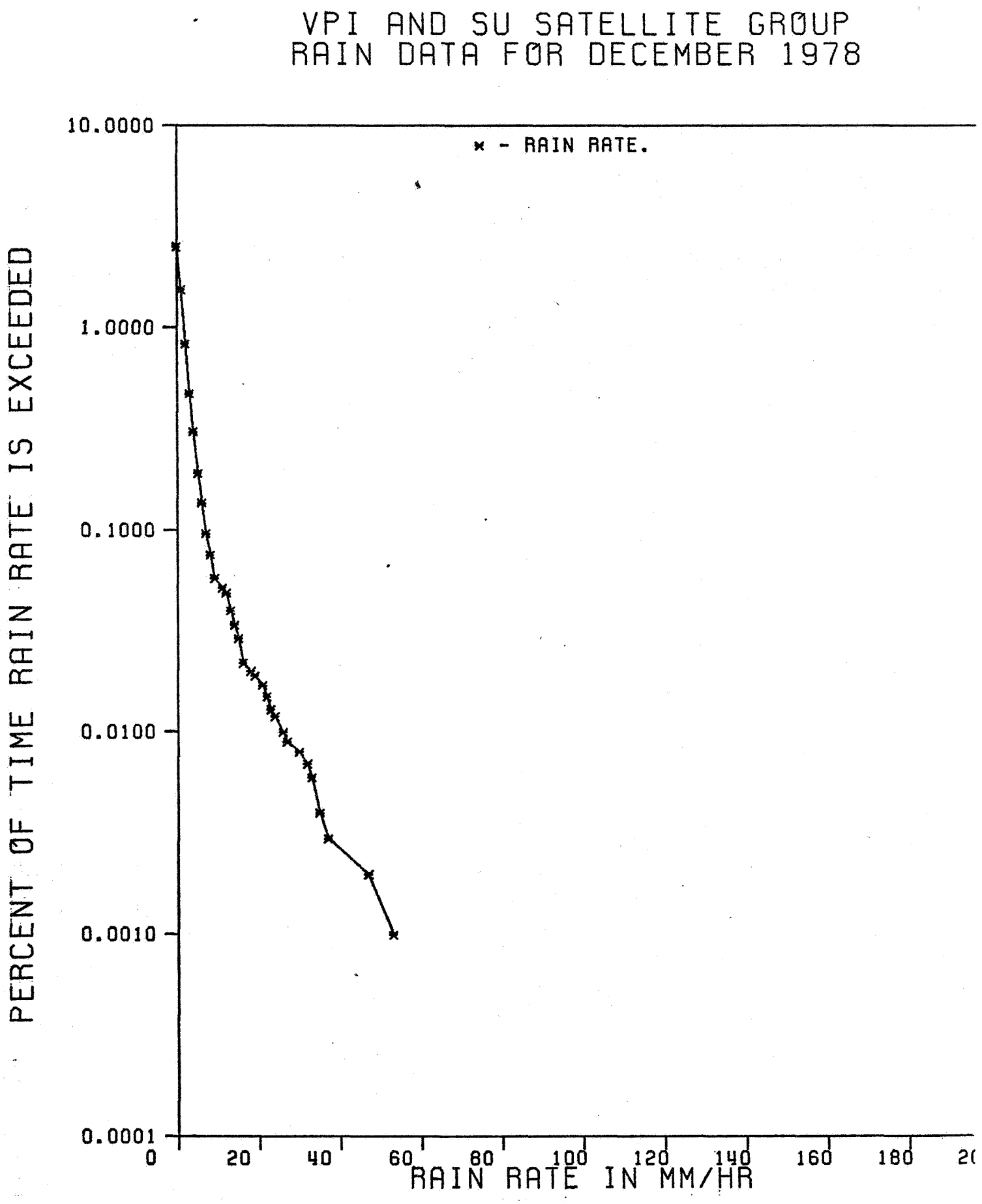

Figure 2.2-22. Rain rate percent of time data for December, 1978.

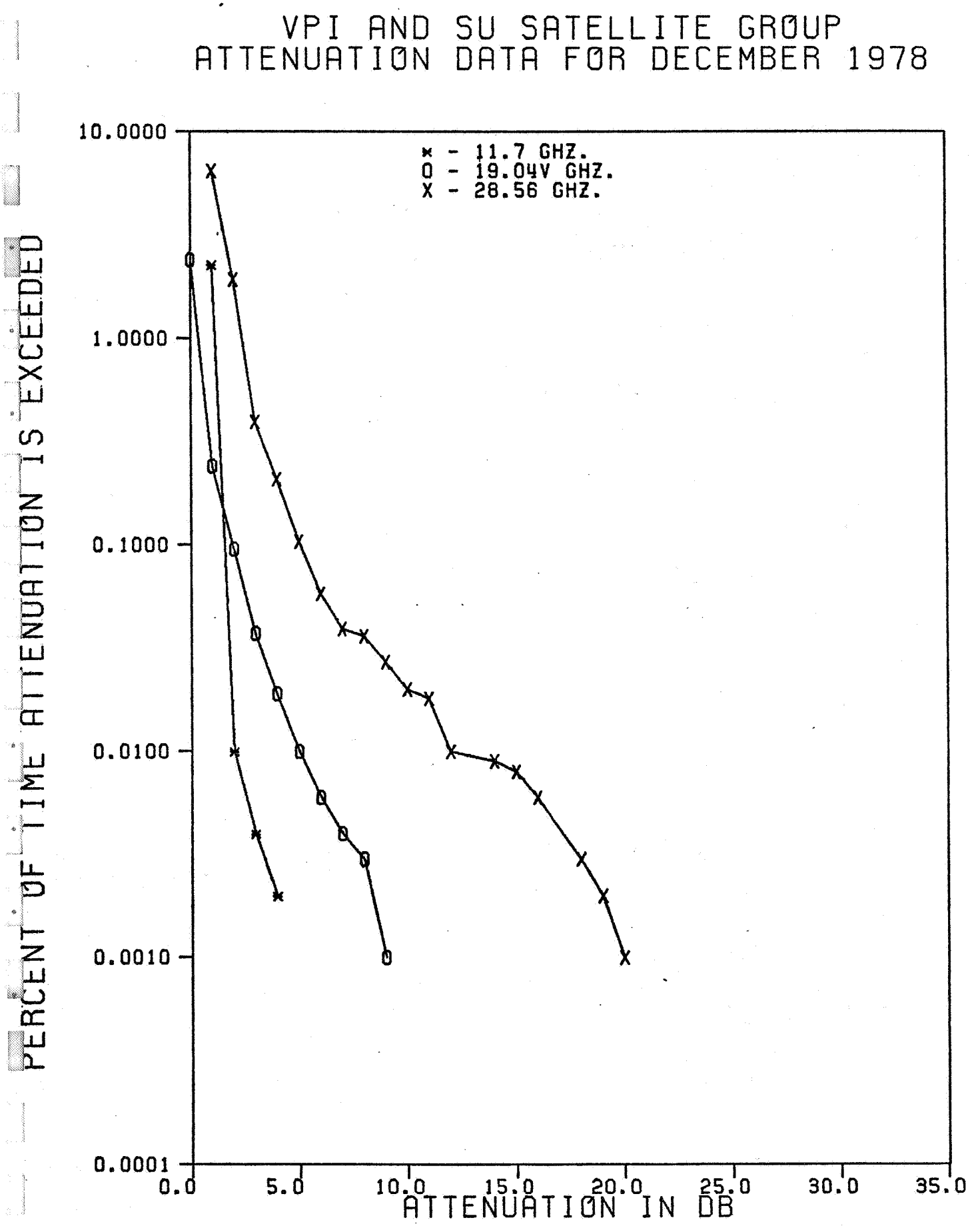

Figure 2.2-23. Attenuation percent of time data for December, 1978.

2.3 Quarterly and Annual Data

To produce annual statistics, data for the three months in each calendar quarter were combined to yield quarterly attenuation and rain rate statistics. Quarterly data were combined to generate half-year data for the warm months (April through September) and the cold months (January, February, March, October, November, and December). The two half-year data bases were then combined to yield the annual percent-of-time plots for rain rate and attenuation shown in Figures 2.3-1 and 2.3-2.

Exact interpretation of the 28.56 GHz data in Figure 2.3-2 is impossible because observations at a low elevation angle (24.5 degrees) have been merged with those from higher elevation angles (44 and 46 degrees). Since attenuation decreases with increasing elevation angle, it is safe to assume that Figure 2.3-2 represents worst-case 1978 annual data for a 28.56 GHz satellite path at 46 degrees elevation.

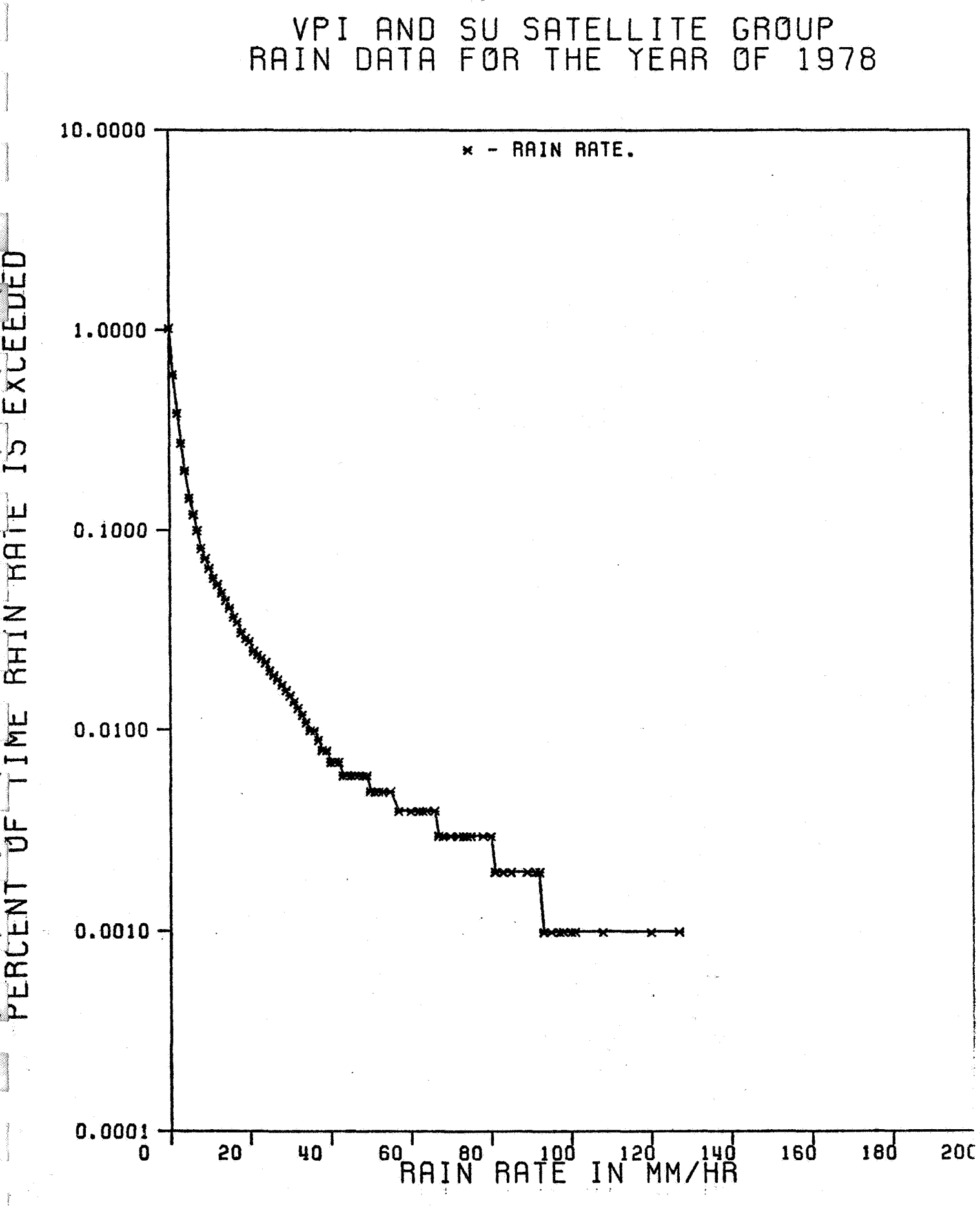

Figure 2.3-1. Rain rate percent of time data for calendar year 1978.

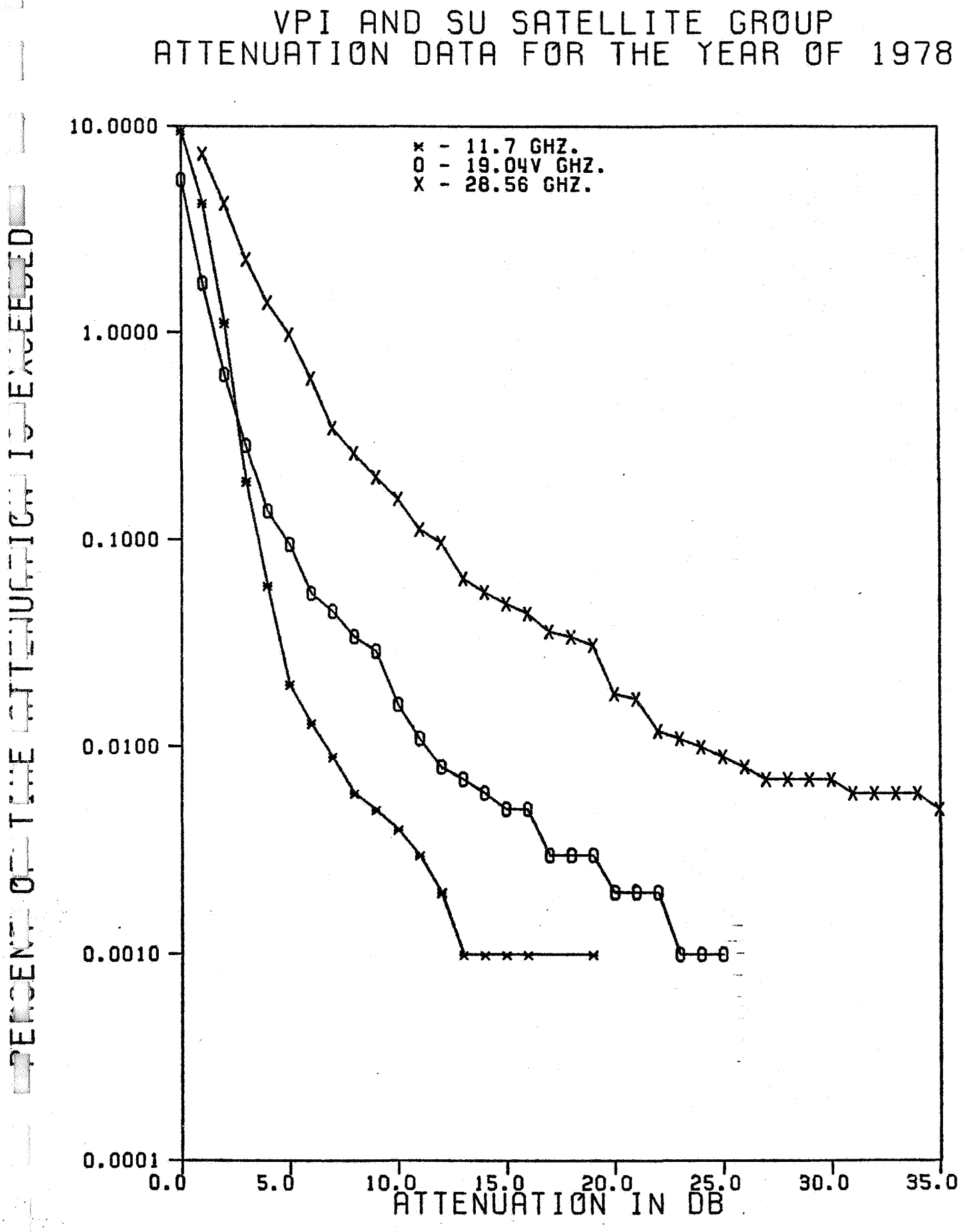

Figure 2.3-2. Attenuation percent of time data for calendar year 1978.

2.4 Attenuation Summary

Table 2.4-1 through 2.4-3 give the percentages of time that attenuations of 5, 10, 15, 20, 25, 30 dB were equalled or exceeded for each month (except January) and for the 1978 calendar year. While the January data are included in the yearly total, they are not compared with the other months because the January data span only a few hours.

Table 2.4-1. Percentages of Time that Selected Attenuations were Equalled or Exceeded in 1978 at 11.7 GHz.

Attenuation, dB	J	F	M	A	M	J	J	A	S	O	N	D	Y
5	**	*	.037	*	.027	.030	.071	.034	.024	*	*	*	.0203
10	**	*	*	*	.004	*	.013	.019	*	*	*	*	.00343
15	**	*	*	*	*	*	.005	*	*	*	*	*	.000727
20	**	*	*	*	*	*	.002	*	*	*	*	*	.000208
25	**	*	*	*	*	*	*	*	*	*	*	*	*
30	**	*	*	*	*	*	*	*	*	*	*	*	*

** Not available
* Not observed (i.e. the attenuation never exceeded this value)

Table 2.4-2. Percentages of Time that Selected Attenuations were Equalled or Exceeded in 1978 at 19.04 GHz.

Attenuation, dB	J	F	M	A †	M	J	J	A	S †	O	N	D	Y
5	**	*	.539	.022	.060	.078	.140	.056	.093	.011	.005	.01	.0955
10	**	*	.030	*	.024	.023	.058	.022	.013	.001	*	*	.0157
15	**	*	*	*	.011	.001	.032	.015 (14 dB)	*	*	*	*	.00530
20	**	*	*	*	.004	*	.011	.012	*	*	*	*	.00249
25	**	*	*	*	*	*	*	.004	*	*	*	*	.000935
30	**	*	*	*	*	*	*	*	*	*	*	*	*

† Scaled Data
* Not Observed (i.e. the attenuation never exceeded this value)
** Not Available

Table 2.4-3. Percentages of Time that Selected Attenuations were Equalled or Exceeded in 1978 at 28.56 GHz.

Attenuation, dB	J	F	M	A	M	J	J †	A	S	O	N	D	Y
5	**	.631	4.79	.808	1.47	.116	.476	1.156	.220	.577	.064	.104	.981
10	**	.002	.781	.188	.106	.053	.186	.211	.103	.005	.007	.020	.159
15	**	*	.212	.005	.046	.029	.108	.047	.053	*	.001 (16 dB)	.008	.0494
20	**	*	.031	*	.025	.018	.073	.018	.014	*	*	.001	.0183
25	**	*	*	*	.017	.005	.054	***	*	*	*	*	.00873
30	**	*	*	*	.010	*	.045	***	*	*	*	*	.00654

*** No points between 23 and 36 dB
** Not Available
* Not Observed (i.e. the attenuation never exceeded this value)
† Scaled

2.5 Comparing Attenuation and Rain Rate

The values of attenuation and rain rate equalled or exceeded for the same percentage of time are of particular importance in rain attenuation modeling and prediction. Tables 2.5-1 through 2.5-3 present these for each integer value of observed attenuation for each month, quarter, and half year of 1978 and for the entire year. The reader is cautioned that the 28 GHz data for the third quarter (JAS), for the warm months (W), and for the year (Y) combine observations from paths with significantly different elevation angles.

For a given rain rate, the month-to-month variations in attenuation are smallest at 11.7 GHz and largest at 28.56 GHz. This is to be expected, as a month's data can be significantly biased by a single intense rain cell which passes through the propagation path but misses the rain gauge or vice versa. Since specific attenuation increases strongly with frequency, rain cells which miss the gauge should provide proportionally more effect at 28.56 GHz than at 11.7 GHz.

A common feature of Tables 2.5-1 through 2.5-3 is the persistence of several dB attenuation at low (1-2 mm/hr) rain rates. This could result from (1) local terrain features guiding some storm cells so that they cross the path but bypass the rain gauges, (2) diurnal signal fluctuations due to orbital motion of the satellites, or (3) both of the above. Since our earth station employs programmed antenna pointing at 11.7 GHz and fixed-pointing at 19.04 and 28.56 GHz (rather than the autotrack used at some stations), some orbital signal variation is unavoidable. At best this represents about 2 dB peak-to-peak

clear weather signal change in 24 hours and occasionally reaches 4 to 6 dB. We have minimized the effect by calculating attenuation from the mean signals for each month (except for January where the short data period permitted peak values were used), but it cannot be eliminated entirely.

Table 2.5-1. 1978 11.7 GHz Equal Probability Attenuation and Rain Rate Values by the Month, Quarter, Half Year (W = warm = April - September; C = cold = January - March and October - December), and Year. A * indicates the first attenuation below the .01% level.

RR	J	F	M	A	M	J	J	A	S	O	N	D	JFM	AMJ	JAS	OND	W	C	Y
1			3	2	2	1	2	1	2	2	2	1		2	2		2	2	
2	1								3				3			2			
3			4															3	
4																			3
5													4						
6						2													
7	2							2	3									4	
8			5*			3													
9															3				
10	3																3		
11							3												4
12				3		4								3					
13								3			3								
14									4		4*		5						
15								4		4*						3			
16	4																		
17																			
18								6	5						4				
19																	4		
20				3*															
21						5		7		5								5*	
22																			
23							4	8						4	5				
24				4															
25																			5
26												2				4	5		
27						6													
28							5		6*						6				
29								9											
30					4														
31														5			6		
32							6	10											6
33				5							5			6	7				
34					5														
35							7					3*							
36	5																7		7*
37																			
38			6										6*		8				
39					6				7										
40	8*					7*							8						
41																			
42														7*					
43																			
44						8													
45					7														
46																			
47												4						6	
48																	8*		8
49															9				
50																			

Table 2.5-1 (continued). 1978 11.7 GHz Equal Probability Attenuation and Rain Rate Values by the Month, Quarter, Half Year (W = warm = April - September; C = cold = January - March and October - December), and Year. A * indicates the first attenuation below the .01% level.

RR	J	F	M	A	M	J	J	A	S	O	N	D	JFM	AMJ	JAS	OND	W	C	Y
51								11											
52							8												
53																		8	
54																			
55																			
56																	9		9
57												5			10	5*			
58																			
59																			
60							9												
61																			
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63			13										13					13	
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92								12*							12				
93																			
94																			
95																			
96																			
97																			
98															13				
99																	13		13
100							T4	13											

Table 2.5-1 (continued). 1978 11.7 GHz Equal Probability Attenuation and Rain Rate Values by the Month, Quarter, Half Year (W - warm = April - September, C = cold = January - March and October - December), and Year. A * indicates the first attenuation below the .01% level.

RR	J	F	M	A	M	J	J	A	S	O	N	D	JFM	AMJ	JAS	OND	W	C	Y
101 102							16								14		14		14
103 104																			
105 106																			
107 108					12												15		15
109 110																			
111 112																			
113 114																			
115 116																			
117 118																			
119 120								14							15		16		16
121 122																			
123 124																			
125 126																			
127 128							19								16		19		
129 130																			
131 132																			
133 134							20								19				
135 136							21	15							20 21		20		20
137 138																			
139 140																			
141 142																			
143 144																			
145 146																			
147 148							24	.							24		21		21
149 150																			

Table 2.5-2. 1978 19.04 GHz V Equal-Probability Attenuation and Rain Rate Values by the Month, Quarter, Half Year (W = warm = April - September; C = cold = January - March and October - December), and Year. A * indicates the first attenuation below the .01% level.

RR	J	F	M	A	M	J	J	A	S	O	N	D	JFM	AMJ	JAS	OND	W	C	Y
1	1		2	1	1	2		1	1	2	0	0	3	2				2	2
2			4	2												1	2		
3	2						2		3						2			3	3
4			6	3	2	4		3				1	4			2			
5								5	4				5	3	3		3	4	4
6				4		5							6					5	
7						6				3	1	2	7	4					5
8	3						3			4			8*					6	
9			10						5	6					4		4	7	
10																			
11					3		4			7*	2							9	
12	4																5		6
13						7			6			3		5	5	3			
14									7										7
15	5			6*			5	6		8									
16				7						9			10		6	4			
17	6				4				8										8
18						8								6			6		
19	7							7				4			7				9
20					5		6												
21										11	3*					5*	7		
22									9										
23															8			10*	
24				8		9	7												
25								8						7		6	8		
26								10				5							
27	8					10	8								9				
28								12			4					7			
29						11		13			5			8	10		9		10
30					6		9				7								
31							10							9		8	10		
32					8									10					
33				9			11		11*		8	6*			11		11		
34					9		12												11
35							13					7		11	12	9			
36	9							14							13				
37					10		14					8					12		12*
38			11*			12*		19							14				
39									12								13		
40	11*					13	15						11		15				13
41														12*					
42			12		11								12				14		
43						14										10			
44														13					
45																			
46					12														14
47																		11	
48																			
49					13		16								16				
50																	15*		15

Table 2.5-2 (continued). 1978 19.04 GHz V Equal-Probability Attenuation and Rain Rate Values by the Month, Quarter, Half Year (W = warm = April - September; C = cold = January - March and October - December), and Year. A * indicates the first attenuation below the .01% level.

RR	J	F	M	A	M	J	J	A	S	O	N	D	JFM	AMJ	JAS	OND	W	C	Y
51								20									16		
52																			
53												9				11			16
54																			
55							15							14					
56																			
57												12				12		12	
58																			
59																			
60					14														
61																			
62													13		17				
63			13															13	
64														15					
65																			
66															18*				
67					17*												17		17
68					18									17					
69																			
70							17										18		18
71																			
72														18					
73					20												19		19
74														20					
75							18								19				
76																			
77																			
78							19												
79																			
80					23														
81														23			20		20
82																			
83																			
84																			
85							20								20				
86																			
87																			
88																			
89																	21		21
90																	22		22
91								22							21				
92								23*							22				
93															23		23		23
94																			
95								24											
96																			
97																			
98								26							24		24		24
99																			
100							21*	27									25		25

Table 2.5-2 (continued). 1978 19.04 GHz V Equal-Probability Attenuation and Rain Rate Values by the Month, Quarter, Half Year (W = warm = April - September; C = cold = January - March and October - December), and Year. A * indicates the first attenuation below the .01% level.

RR	J	F	M	A	M	J	J	A	S	O	N	D	JFM	AMJ	JAS	OND	W	C	Y
101 102							23								14				
103 104																			
105 106																			
107 108					25														
109 110																			
111 112																			
113 114																			
115 116																			
117 118																			
119 120								29											
121 122																			
123 124																			
125 126								30											
127 128															16				
129 130																			
131 132																			
133 134															27		26		26
135 136							26								28 29		27 28		27 28
137 138																			
139 140																			
141 142																			
143 144																			
145 146																			
147 148							28								30		29		29
149 150																			

Table 2.5-3. 1978 28.56 GHz V Equal-Probability Attenuation and Rain Rate Values by the Month, Quarter, Half Year (W = warm = April - September; C = cold = January - March and October - December), and Year. A * indicates the first attenuation below the .01% level.

← D2 →						← D1 →			← D3 →				D2	D2	D3				
RR	J	F	M	A	M	J	J	A	S	O	N	D	JFM	AMJ	JAS	OND	W	C	Y
1	3		7	10	7	2	4	9	6	5	2	2		8		3	7	6	6
2	4					4							7		8		8		
3			12				5		9			3	10			4	9	7	
4	5		14		8		6	12		6	3	4	12		9			8	9
5	6			12		7	7	14						10		4	10		10
6	7											5	14		10			11	
7	8					9	8		10		4		17					12	11
8	9					10			11		5			11	11	6	11	13	12
9	10		20		9					7*		6							
10								16	12		6				12			18	13
11	12					11	9			8	7						12		14
12							10		13				20*		13*				
13					10		11		14			7	21			7			15
14				13			12		15		9	8			14	8	13		
15				14*		12	13			9				12		9			
16	17			15	11							9					14		16
17	19								17						15	10			18
18	20							17	18			10		13	16		15		19
19												11				11*		20	
20				16	12		14							14				21*	
21	22						16			11	10*						16		
22	23				14	15			19						17				
23								18	21					15					
24				17											18		17		
25	24					16							23						
26					15		18					12			19		18		
27							19					14*			20	12			20
28						17									21	13			21
29	26					19	21				11		24	16			19		
30					16		22				14	15				15	20		
31					17		23				16			17	22		21		
32					19		24	19					25	19	23			22	
33				19		21			22*		17	16		20	24	17	22	23	
34							28							21	25		23		
35							30							22	28		24		
36	27				20			23							30				24*
37					21		34					18		23	33	18	25	24	
38			22*			24*		36							34		26		
39							35		25						35		28		
40	29*							54					26		36		29	25	28
41						25								24*			30		
42					23		37						27		38		32		30
43																			
44						26								25			33		
45																	34		31
46					24		38							26	39				33
47							39					19				19			34
48					26									27			35*		
49					27										41				
50															44		36		

Table 2.5-3 (continued). 1978 28.56 GHz V Equal-Probability Attenuation and Rain Rate Values by the Month, Quarter, Half Year (W = warm = April - September; C = cold = January - March and October - December), and Year. A * indicates the first attenuation below the .01% level.

	← D2 →						←D1→		← D3 →				D2	D2	D3				
RR	J	F	M	A	M	J	J	A	S	O	N	D	JFM	AMJ	JAS	OND	W	C	Y
51								57						28	46		37		
52							44										38		
53												20				20		26	
54																			
55						28											39		37
56																			
57												25				25		27	
58																			
59																			
60					29												41		
61																			
62																	43		41
63			26										29	29				29	43
64					31									31			44		44
65																			
66																	46		
67					35*												47		47
68					36									35					
69																			
70																			
71																			
72														36					
73					41														
74														41					
75																			
76																			
77																			
78															49				
79																			
80					47														
81														47			49		49
82																			
83															53				
84																			
85							49								54		50		50
86																			
87																			
88																			
89															57		54		54
90																			
91							57*	62											
92								65*							61		57		57
93															62		62		62
94																			
95								70							63				
96																			
97																	65		65
98								74											
99															70				
100								78									70		70

Table 2.5-3 (continued). 1978 28.56 GHz V Equal-Probability Attenuation and Rain Rate Values by the Month, Quarter, Half Year (W = warm = April - September; C = cold = January - March and October - December), and Year. A * indicates the first attenuation below the .01% level.

	← D2 →						← D1 →		← D3 →				D2	D2	D3				
RR	J	F	M	A	M	J	J	A	S	O	N	D	JFM	AMJ	JAS	OND	W	C	Y
101 102							61												
103 104																			
105 106																			
107 108					50														
109 110																			
111 112																			
113 114																			
115 116																			
117 118																			
119 120								82											
121 122																			
123 124																			
125 126																			
127 128															74				
129 130																			
131 132																			
133 134															78		74		74
135 136							74	87									78		78
137 138																			
139 140																			
141 142																			
143 144																			
145 146																			
147 148							82										82		82
149 150																			

3. ISOLATION

During 1978 we collected nearly equal amounts of isolation and attenuation data. Work is presently in progress on the isolation statistics, and these will be presented at a later time.

A question of general interest is the extent to which isolation data and statistics may be inferred from attenuation measurements alone. One approach taken by several groups has been to look at theoretical or empirical equations of the form

$$I = U - V*\log_{10}(A)$$

where I and A are simultaneous decibel values of isolation and attenuation. Our experience has been that sometimes this equation provides an excellent fit to the data and sometimes it does not; there is considerable month-to-month variation that is as yet unexplained. Table 3-1 presents the least-square fit U, V values that we obtained at each frequency for each month in 1978 along with information on the number of points used and the goodness of the fit obtained (R-squared). We are continuing to study the relationship between isolation and attenuation and will present a detailed report on it in the future.

Table 3-1. Results of least-square fitting $I = U - V*\log_{10}(A)$ to 1978 isolation and attenuation data. Except where noted, values are for $3 < A < 30$ dB. The quantity R^2 indicates goodness of fit (1.0 indicates a perfect fit) and P is the number of data points used in the analysis.

Month	11.7 GHz				19.04 GHz V				19.04 GHz H				28.56 GHz			
	U	V	R^2	P	U	V	R^2	P	U	V	R^2	P	U	V	R^2	P
J	30.57	1.71	.00	99	36.16	9.54	.14	331	30.32	14.96	.24	2157	35.02	1.75	.01	1187
F*	33.55	-11.63	.00	2471	19.53	26.96	.13	2515	12.45	-2.35	.00	4534	39.87	21.34	.46	4589
M	35.74	18.13	.47	3667	28.52	6.42	.08	255	20.48	7.29	.02	2731	41.64	26.83	.54	10350
A	25.33	-.17	.00	87	**	**	**	**	**	**	**	**	27.86	-3.06	.11	2761
M	28.14	5.69	.03	1420	23.51	-3.62	.02	85	19.73	12.55	.13	41	31.55	3.67	.04	6991
J	36.70	15.51	.61	61	20.42	-3.50	.01	154	24.55	11.87	.14	193	38.39	12.05	.19	189
J	28.22	8.04	.11	1255	36.88	10.67	.28	277	28.56	16.41	.58	191	**	**	**	**
	43.23	21.96	.80	74	(5 < A < 30)											
A	39.73	18.79	.70	38	30.77	- .50	.00	127	15.84	-.30	.00	2913	**	**	**	**
S	62.05	50.54	.62	146	36.88	7.92	1.00	12	17.16	3.04	.06	1326	23.56	3.66	.06	1895
O	35.87	17.64	.21	292	27.71	4.10	.02	445	27.04	10.39	.27	1332	29.59	3.18	.01	3537
N	4.92	-35.32	.16	1115	38.30	12.46	.87	22	33.12	20.12	.95	5	24.13	-9.58	.07	589
D	42.13	24.91	.37	8	43.82	17.85	.37	78	32.40	19.48	.37	89	28.55	.59	.00	1690

* No rainfall.
** No data collected.

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15. Supplementary Notes

16. Abstract

This report presents monthly and annual percent-of-time data on ground rain fall rate and attenuation on satellite downlinks at 11.7 GHz, 19.04 GHz, and 28.56 GHz. It compares equal-probability values of attenuation and rain rate for monthly, quarterly, half-year periods and for the entire year. Regression equations relating cross polarization isolation to the logarithm of attenuation are presented for each month of 1978.

17. Key Words (Selected by Author(s))	18. Distribution Statement
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